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QUESTIONS AND ANSWERS

FROM THE

AMERICAN MACHINIST

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FRANK RICHARDS

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WHY THIS BOOK?

THE READERS of the AMERICAN MACHINIST are also thinkers and inquirers. They want to know things, and have a habit of asking questions. More than ten thousand questions have been answered in the columns of the AMERICAN MACHINIST. They were answered in the paper because the answers were of interest to many others besides the original inquirers. Some were of only temporary interest, while others related to enduring principles and practices, and may be assumed to be of nearly as much interest and help at one time as at another. We have collected here about ten per cent. of the questions which have been asked and publicly answered, believing that they will still be of value to many. No minute classification or arrangement has been attempted, as the range of topics is so extensive.

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Steam.

1. Q.—In reference to steam, what is meant by absolute, initial and terminal pressures?

   A.—Absolute pressure is the pressure from vacuum. An ordinary steam gage shows the pressure above atmosphere; if to this is added the pressure of the atmosphere, very commonly considered as 14.7 pounds per square inch, we have absolute pressure. Initial pressure is the pressure of steam in the cylinder of a steam engine at or near the beginning of the stroke of the piston. Terminal pressure is the pressure that would be in the cylinder at the end of the stroke if the exhaust valve had not opened.

2. Q.—What is the rule for finding the temperature of steam from the pressure?

   A.—The following rule is deducted from Nystrom's formula: Multiply the 6-root of the pressure by 200, and from this subtract 101; the remainder will be the temperature. The pressure is to be taken as absolute; that is, 14.7 pounds must be added to the pressure indicated by the steam gage. To find the 6-root find the square root of the cube root.

3. Q.—How is the pressure of saturated steam due to a given temperature ascertained?

   A.—To the temperature add 101, divide the sum by 200, and raise the quotient to the sixth power.

4. Q.—If two vessels of the same size are partially filled with water, one being half full and the other a quarter full, and subjected to the same degree of heat, would the steam pressure be the same in both cases? If so, why?

   A.—If the temperature is the same in both vessels, and if the water is not wholly evaporated in either vessel, the pressure in one vessel will be equal to the pressure in the other. The pressure of steam always depends on its temperature and not on the amount of water in the vessel. If, for instance, the temperature is 70 degrees Fahrenheit in both vessels, the pressure in each will

be 0.36 of a pound per square inch; if the temperature is raised to 212 degrees in both vessels then the pressure will be 14.7 pounds per square inch in each vessel; or if the temperature is raised to 220 degrees the pressure will be 17.2 pounds. In general, if heat be gradually applied to raise the temperature more vapor will form, but the pressure will not rise above a fixed value for each temperature, independent of the volume of water in the vessel; but when the water is all evaporated in one vessel, and some is left in the other, and the temperature then increased in both vessels, the above will not hold true.

5. Q.—A asserts that water does not exist at a temperature above 212 degrees, even in a boiler where the pressure is above that of the atmosphere. B says that boiling water always has the same temperature as the steam which is produced from it, and that when the pressure rises above that of the atmosphere the temperature of the water rises above 212 degrees. Which is correct?

A.—The statement of B is correct. When steam is in contact with the water from which it is generated the steam and water have the same temperature. A rise of pressure cannot take place without a corresponding rise in temperature. The physical condition of saturated steam is such that it is ready on the smallest increase of pressure, or decrease of temperature, to yield some portion of liquid. For any given pressure there is but one temperature and one density

6. Q.—Can water be vaporized without allowing room for expansion; or could steam, if kept at a high temperature, be reduced to the space it occupied as water, and still be steam? Or, again, suppose we have a closed receptacle of great strength filled with water; we heat it to redness; what is the result, highly heated water or steam under an enormous pressure?

A.—You cannot convert water into steam without leaving some room in the vessel for the steam. If the vessel is completely filled with water no steam will be formed, even if it is heated to the highest temperature that metal can stand. If, under these conditions, the water is allowed to escape, it will rush out in the form of steam, and a portion of the water remaining in the vessel will at once be formed into steam of a pressure depending on the temperature.

7. Q.—What weight of steam will one pound of water make?

A.—One pound of water will make one pound of steam.

8. Q.—How much water will it take to condense one pound of steam?

A.—That will depend on the temperature of the steam, of the cooling water, and of the hot well or receptacle into which the air pump delivers the products of the condenser. Let T_1 be the temperature of the steam; T_0 the temperature of the cooling water, whose quantity in pounds is Q; T_2 the temperature after condensation, or that of the hot well. We then have

$$Q = \frac{1{,}114^\circ + (0.3 \times T_1) - T_2}{T_2 - T_0}$$

To show the application of this formula we will take the following example: Find the amount of injection water required for an engine exhausting the steam at a temperature of 193 degrees, the temperature of the injection water is 60 degrees, and the temperature of the hot well is to be 120 degrees—

$$Q = \frac{1{,}114^\circ + (0.3 \times 193^\circ) - 120^\circ}{120^\circ - 60^\circ} = 17.53 \text{ pounds.}$$

That is, the amount of injection water is 17.53 times the weight of the steam for this particular case.

9. Q.—What per cent. of heat units in coal is transferred to the steam in the best type of modern steam boilers?

A.—In a good boiler a pound of coal should evaporate 10 pounds of water from and at 212 degrees Fahr. To evaporate one pound of water under these conditions requires 966 units of heat, hence for 10 pounds of water 9,660 units of heat will be required. The units of heat in one pound of coal we may average at 14,000, hence the per cent. of units of heat in coal transferred to the steam is about 69 per cent. Of course, this must be taken as an approximation, as much depends on the quality of the coal used.

10. Q.—What per cent. of heat units of the steam in the boiler is converted into work in a high-pressure engine, condensing engine, compound and triple-expansion engine?

A.—The consumption of a good quality of coal per indicated horse-power per hour with a good triple-expansion engine may be taken at 1½ pounds. Now, assuming again that each pound of coal when completely burned gives out 14,000 units of heat,

then for 1½ pounds of coal 21,000 units of heat will be given out per hour, or 350 units of heat per minute. Assuming that each unit of heat is equivalent to 772 foot-pounds of work, then 350 units of heat should be equivalent to $350 \times 772 = 270{,}200$ foot-pounds of work per minute. But the 1½ pounds of coal, when a triple-expansion engine is used, give us one horse-power only, or 33,000 foot-pounds of work per minute, hence of the total heat of combustion only,

$$\frac{33{,}000 \times 100}{270{,}200} = 12.2 \text{ per cent.}$$

is made to do useful work in the cylinder. We have seen that about 69 per cent. of the heat of combustion is transferred to the steam in the boiler, hence about 18 per cent. of the heat of steam is made to do useful work. The coal consumption per indicated horse-power per hour is about 4 pounds with surface condensing engines using steam of 30 pounds gage pressure; 3¼ to 3½ pounds of similar engines of best make and large size; 2½ pounds with compound engines of moderate size; 1¾ pounds with large compound engines, and 1½ pounds with triple-expansion engines. With this data you can make your own computation for the other classes of engines.

11. Q.—If steam is raised in a boiler to 80 pounds pressure, how high will the water be forced in a ¾-inch or 1-inch pipe attached to the bottom of the boiler?

A.—Assuming that the temperature of the water in the pipe will remain at about the temperature of the atmosphere, it will rise to about 184 feet.

12. Q.—Mr. Charles T. Porter says that 5 cubic feet of saturated steam at 20 pounds pressure weigh nearly 10 per cent. more than 1 cubic foot at 1000 pounds pressure, the exact figures being .255 and .233. Now, I cannot understand why the 5 cubic feet at 20 pounds can weigh more than 1 cubic foot at 100 pounds, since both must contain the same amount of water.

A.—It happens that Mr. Porter is correct, as he is quite in the habit of being. Steam does not conform to the theory of a perfect gas, and, indeed, it cannot be brought under the conditions assumed for the action of a perfect gas. At constant temperature the weight per unit of volume should be directly as the pressure, but saturated steam at different pressures has also

different temperatures, and, consequently, at the higher pressures the weight falls off somewhat.

13. Q.—How can I compute the force of water when confined and heated from 32 degrees to 212 degrees? Or, in other words, suppose I have a cubic foot of water in a closed vessel at 32 degrees, and heat to 212 degrees, what will be the pressure?

A.—This is a question that it is impossible to answer. Theoretically, the pressure would be equal to that required to mechanically compress it from the larger volume to the smaller, and this has never been done. A pressure of 2,500 pounds per square inch, it is said, will so increase the density of water that a cubic foot of it will weigh half a pound more than without the pressure; but the difference in weight at 32 degrees and at 212 degrees is more than 2½ pounds.

14. Q.—B asks for a method of measuring the steam used by a tenant for different purposes and in varying quantities.

A.—The only steam meter of which we have any knowledge is the one designed by Mr. C. E. Emery for the New York Steam Company. This consisted of a self-adjusting hole, through which the steam passed. A loaded piston or diaphragm kept the hole of such size as to maintain a constant difference of two pounds pressure between the two sides. A pencil and strip of paper (driven by clockwork) made a permanent record of the varying size of the hole, which was used as a measure of the steam flowing through the meter. The meter is similar in principle to the measuring box used in the mining sections of the West for measuring the flow of water. This box has an adjustable hole, which is adjusted to keep a constant head in the box, when the size of the hole becomes a measure of the water flowing.

15. Q.—What is the volume of steam when it is at 60 pounds per inch above atmosphere?

A.—At 60 pounds gage pressure (equal to 75 pounds absolute) the steam in boiler is about 350 times the volume of the water evaporated. Or, a pound weight of steam at 60 pounds pressure above atmosphere occupies a space of 5.7 cubic feet. This is for steam termed saturated, such as that which has just been formed in a boiler. If superheated, the volume at any pressure depends on the circumstances under which such extra heat is imparted.

16. Q.—What is meant by pressure above the atmosphere?

A.—The atmosphere exerts a pressure of practically 15 pounds per square inch at sea level on the average (14.7 pounds per inch being the yearly mean or average value). This pressure is above zero, or "nothing," and as such is what is termed absolute pressure. Boiler gages measure pressure above atmosphere, since they show zero when open to the air. In steam pressure tables, pressures below 15 (or 14.7) pounds per inch are sometimes called minus in the same way that temperatures are called minus when below the zero on the scale.

17. Q.—Does the pressure of the atmosphere on the outside of a boiler make it capable of withstanding more steam pressure than if there were no outside pressure; and if so, why?

A.—The pressure of the air on the outside of the boiler is equal to, say, 14 7-10 pounds per square inch, consequently it balances the same pressure on the inside. If the air were exhausted from the boiler, the tendency of the external air would be to collapse the boiler. The ordinary steam gage does not register pressure below the pressure of the atmosphere, so that if the gage shows 10 pounds pressure there is really a pressure of 10 + 14 7-10 = 24 7-10 pounds. Only 10 pounds is resisted by the boiler, but if it were not for the pressure of the atmosphere on the outside, the boiler must resist the total 24 7-10 pounds.

18. Q.—Would there be any danger in putting a closed piece of 5 or 6-inch pipe containing water in a stove and raising a high pressure in it if the water line were kept above the fire?

A.—Decidedly yes; unless you have it fitted with safety valve and pressure gage. The position of the water line would have little to do with it. Do not try, if you value your life or property.

19. Q.—How much pressure could a 30-inch piston driven by 100 pounds of steam exert if there was no outlet for the exhaust?

A.—Disregarding the momentum of the parts, the piston would come to a standstill as soon as the pressure on its two sides was equal—the area of the two sides being assumed to be the same.

20. Q.—If a given volume of steam at 100 pounds gage pressure is compressed, what will be the consequence? Will the pressure re-

main at 100 pounds, with condensation of all the steam except enough to maintain the pressure, or will the pressure rise?

A.—The pressure will, of course, rise, and no condensation need necessarily occur. The compression of steam to a higher pressure occurs at every stroke of any good steam engine, as evidenced by indicator diagrams. With the compression and accompanying rise of pressure there will be also a corresponding rise of temperature.

21. Q.—How can an injector using steam at 40 pounds pressure force water into a boiler at 160 pounds pressure?

A.—Briefly stated, it is because the velocity of the issuing steam at 40 pounds pressure is greater than the flow of water under 160 pounds pressure. The steam passing through the injector is condensed, preserving its velocity, which, as just explained, being greater than the flow of water under 160 pounds pressure, renders it possible to add more water to that of condensation, thereby reducing its velocity until it is just sufficient to overcome the resistance and enter the boiler.

22. Q.—My friend claims that high-pressure steam is always dry, while steam of a low-pressure is always wet. I claim that steam of any pressure is wet. Which is right?

A.—Steam in contact with the water from which it is formed may be wet or dry, according to circumstances and without reference to the pressure. Dry steam—so called—is steam without any excess of heat, and in which there is no water except what is in the form of steam, but since such steam can part with no heat without condensation, and since it usually contains a little water, carried off mechanically, it is seldom met with in practice. Superheated steam is necessarily dry steam, as it contains heat in excess of that due to the pressure, which excess of heat must be parted with before condensation results.

23. Q.—Suppose we have a pipe 8 inches diameter and 1,500 feet long, covered with wood 4 inches thick, lined inside with tin, and put in the ground for carrying steam to an engine. What will be the pressure at the engine, the pressure at the boilers being 120 pounds?

A.—The pressure at the engine may be practically the same as at the boiler. It will depend somewhat upon whether the pipe is straight or has elbows in it, and also as to whether the

pipe is large for the amount of steam carried through it. If it is large, the pressure will be practically maintained throughout its length, whereas if it is small, so that the current through it is rapid, the pressure may fall considerably; but the amount of this fall cannot be determined unless all the conditions are known.

24. Q.—I want to condense steam at a temperature of 220 degrees Fahr. by means of air at a temperature of 60 degrees. How many cubic feet of air will it take to condense 1 cubic foot of steam under the above conditions?

A.—This problem can be solved in the following way: Weight of 1 cubic foot of steam at 220 degrees = .0435 pound. Total heat of steam above water at 212 degrees = 968. Heat units to be taken out of 1 cubic foot of steam = 968 × .0435 × 1 = 42.116. Say that the air to condense the above may be heated from 60 to 180 degrees = 120 degrees. Weight of 1 cubic foot of air at 60 degrees = .0761. Specific heat of air = .2377. Then 120 × .0761 × .2377 = 2.17 heat units to raise 1 cubic foot of air from 60 to 180 degrees; and 42.116 ÷ 2.17 = 19.4, say 20, cubic feet of air required to condense 1 cubic foot of steam at 220 degrees to water at 212 degrees.

25. Q.—Will a steam pipe resting on wood set the wood on fire?

A.—Should the steam become superheated there is danger of the wood taking fire. It is bad practice to allow steam pipes to rest on wood in any case, and it should always be avoided.

26. Q.—What is a steam loop?

A.—A steam loop is simply a method of piping by which water of condensation is returned to steam boilers. In its simplest form it consists of three pipes, which are called respectively the riser, the horizontal and the drop leg. When the steam loop is used for returning to the boiler the water of condensation and entrainment from the steam pipe through which the steam flows to the cylinder of an engine, the riser is generally attached to a separator; this riser empties at a suitable hight into the horizontal, and from thence the water of condensation is led into the drop leg, which is connected to the boiler, into which the water of condensation is fed as soon as the hydrostatic pressure in the drop leg, in connection with the steam pressure in the pipes, is sufficient to overcome the boiler pressure. The action of the device depends on the following principles: Difference of pres-

sure may be balanced by a water column; vapors or liquids tend to flow to the point of lowest pressure; rate of flow depends on difference of pressure and mass; decrease of static pressure in a steam pipe or chamber is proportional to rate of condensation; in a steam current water will be carried or swept along rapidly by friction.

27. Q.—A horizontal pipe a mile long is connected to a boiler carrying 200 pounds of steam pressure. The pipe is closed at the other end, and a gage placed at the boiler end and another at the further end of the pipe. Would there be any difference in the pressure indicated by the two gages? Condensation is not to be considered.

A.—There will be no difference in the pressure indicated.

28. Q.—Could there be any friction in the pipe without an opening?

A.—No. There can be no friction without a flow of steam.

29. Q.—Would there be any difference in the pressure if the pipe was vertical?

A.—Yes; the gage at the bottom of the pipe would show a greater pressure, the difference being equal to the weight of the steam.

30. Q.—How can I compute the safe steam pressure in a cast-iron pan whose sides are ⅞ inch thick, and the surface exposed to the steam pressure of each side is 3.157 square inches?

A.—From your description we assume that the pan is simply a hollow cube, the inner surface of each side containing 3.157 square inches. For so small a casting it is sufficient for practical purposes to compute the safe shearing resistance of each side of the cube. The length of the side of each surface is equal to the square root of 3.157 square inches = 1.78 inches, and the surface to be sheared is equal to $4 \times 1.78 \times \frac{7}{8} = 6.23$ square inches. Assuming that 4,000 pounds is the safe shearing stress for cast iron, the total resistance to shearing will be $6.23 \times 4{,}000 = 24{,}920$ pounds; dividing this by the area of one surface (3.157), we have $\frac{24{,}920}{3{,}157} = 7{,}893$ pounds per square inch.

31. Q.—Will a boiler 30 inches diameter stand twice the pressure that one 60 inches diameter will stand?

A.—Other things being equal, yes.

32. Q.—Does the length of a boiler make any difference in the pressure it will stand?

A.—If properly supported the length need not be considered.

33. Q.—Will a boiler stay 12 feet long hold double the strain that one 24 feet long will hold?

A.—If the same in construction and material, the strength will be the same without reference to the length.

34. Q.—How do you calculate the tensile strength of a round bar of iron?

A.—Find the area of the cross section of the bar in square inches and multiply it by the tabulated tensile strength of the material. Thus, if you know, or assume, that the material will safely bear a tensile strain of 5,000 per square inch, and wish to know how much a 2-inch bar of round iron will hold, first find the area of the 2-inch bar, which is 3,1416 inches, and this multiplied by 5,000 equals 15,708 pounds, which is what the 2-inch bar will stand with safety.

35. Q.—Why are the strains on the longitudinal seams of a boiler double those on the roundabout seams, and why are the longitudinal seams double-riveted?

A.—Assume a boiler 96 inches diameter, ½-inch iron, under 100 pounds pressure. The pressure to rupture it transversely will be $96 \times 100 = 9{,}600$ pounds, borne by two sections of iron, altogether one inch of metal. The pressure to pull the boiler apart in the direction of its circumference will be the area multiplied by the steam pressure, that is, $7{,}238.24 \times 100 = 723{,}824$ pounds. The circumference of the shell is 301.59 inches, which divided by 2 (the iron is ½ inch thick) gives 150.79 inches of iron to stand this strain. This is $723{,}824 \div 150.79 = 4{,}800$ pounds per inch. It is for this reason that the longitudinal seams are double-riveted.

36. Q.—In designing a boiler to carry 150 pounds of steam, how much anthracite and bituminous coal would you allow per square foot of grate surface per hour, and how many pounds per indicated horse-power?

A.—In ordinary practice you can allow 12 pounds anthracite and about 16 pounds bituminous coal, with natural draft.

37. Q.—What is the difference between a flue which closely fits the hole in the sheet and one that fits loosely? That is to say, is

there any bad effect from having to expand the tube about a sixteenth of an inch?

A.—It is always best not to make the flue holes any larger than necessary for the flues, so as to reduce the amount to be expanded as much as possible; the more a flue has to be expanded the more it is liable to injury, and, besides this, a longer time for expanding will be required. The holes should be just large enough to push the flues through them, and for this purpose we believe 1-32 inch diameter to be ample; less will be better.

38. Q.—What is the use of the bridge wall in the furnace of steam boilers?

A.—The object of the bridge wall is to form a combustion chamber, so that the uncombined gases of the air and fuel may be brought by mixture into contact while still at a sufficiently high temperature for combustion.

39. Q.—What is the difference between a hard and soft patch on a boiler; which one should be put on the crown sheet? And should it be put on the inside or outside of the sheet, and why? If put on the outside, A claims it will form a pocket for scale to collect, and B claims if put on the inside there will be no advantage gained. Which one is right? The patch is to be 3½ feet from front flue sheet and in the center of crown sheet. The feed enters at the bottom of the rear end of boiler; the feed pipe is run to within 18 inches from the patch; the boiler is 4½ feet diameter and 16 feet long.

A.—A soft patch is one which is bolted to the boiler, and is made tight by means of red lead or some similar substance. A patch of this kind is seldom used for high steam pressure. A hard patch is one that is riveted to the boiler and calked. Sometimes a hard patch is screwed to the boiler by means of screw bolts, the boiler sheet is tapped, and the holes in the patch are countersunk to a conical form, and receive the heads of bolts of a corresponding form; the outer portions of the heads have the appearance of rivet heads. In other cases the holes in the patch are not counterbored, but simply faced off square with the axes of the bolts by means of a rotating cutter after the patch has been put in place so as to obtain a good fair bearing for the bolt heads. In either case, when the job is done it is difficult to

decide whether the patch has been riveted or screwed to the boiler. We prefer not to put a patch of any kind on the crown sheet. It is better and safer practice to put in a new crown sheet; but if necessity demands a patch, we should use the hard patch and, if possible, put it on the inside of the boiler, which will tend to prevent any sediment collecting on it, and avoid the danger of burning it. Another advantage of placing it inside is that the stress on the bolts will be much reduced. The disadvantage of placing it inside is that the patch cannot be readily calked; in fact, it may be an impossibility to do so, and therefore the patch will have to be put on the outside of the crown sheet, which, in our opinion, is a dangerous practice.

40. Q.—Is it good practice to keep the valve closed on feed pipe between the check valve and boiler when not feeding?

A.—It is bad practice to close this valve, excepting in a case of emergency, as there is danger of neglecting to open it when the boiler is doing duty.

41. Q.—Is there any difference between the terms "high duty" and "high pressure" steam pumps?

A.—The term "duty" refers to the economy of the pump or pumping engine. It is the number of foot-pounds of work done by the consumption of 100 pounds of coal. Thus, the duty of a pumping engine that will do the equivalent of lifting 100,000,000 pounds 1 foot high for 100 pounds of coal consumed is said to be 100,000,000. This has no reference to the capacity of the engine or the pressure. The term high-pressure pump simply refers to the comparatively high head or pressure against which the pump is capable of working.

42. Q.—What is the proper rule used in the United States for computing the horse-power of a boiler?

A.—The rule generally used is known as "The Centennial Rule," and requires that the boiler shall have a capacity to evaporate 30 pounds of water per hour into dry steam from feed water at 100 degrees Fahrenheit, and under a pressure of 70 pounds per square inch for each horse-power. To get such an evaporation (which equals 34.5 pounds from and at 212 degrees Fahrenheit) under ordinary working conditions for boilers working on land they should have 11.5 square feet of heating surface and ⅓ square foot of grate surface per horse-power.

43. Q.—What is the formula for the efficiency of triple and quadruple-riveted butt-strap boiler seams?

A.—The following are the Philadelphia rules for the strength of boiler seams, which are probably the best that have been made into law. Formula A: From the pitch of the rivets subtract the diameter of the holes and divide the remainder by the pitch of the rivets. The result is the percentage of strength of the net section of the sheet at the seam as compared with the solid part of the same sheet. Formula B: The continued product of the area of the hole, the number of rows of rivets in the seam, and the shearing strength of the rivet per square inch of section, divided by the continued product of the pitch of the rivets, the thickness of the sheet, and the tensile strength of the sheet per square inch of section equals the percentage of the strength of the rivets as compared with the strength of the solid part of the sheet. It is further provided that the shearing strength of iron rivets shall not be considered in excess of 40,000 pounds. The above rules apply to any number of rows of rivets. In computing the actual strength of a boiler the lowest value of the percentage found by (A) or (B) is taken.

44. Q.—Would a cast-iron dome secured by screws and gaskets be practicable on steam boilers?

A.—Cast-iron domes are frequently used on small boilers—up to, say, 20 horse-power. They should, however, be secured by rivets and calking.

45. Q.—Why in porcupine boilers are the pipes closed up in the forge instead of using a threaded cap?

A.—We presume to insure against leaks and corrosion of the joints.

46. Q.—I have been told that in order to test a boiler I should fill it with water so that the water flows out of the safety valve; then shut this valve and start a fire under the boiler, and raise the pressure up to the point at which I wish to test it. Is there any danger in testing a boiler in this way?

A.—Boilers are sometimes tested as you describe, but we do not believe it to be as good as the following way: Close all the openings in the boiler as securely as possible, but keep the safety valve open until the boiler is completely filled with water. Then, after closing the safety valve and loading it to the required test

pressure, raise the pressure by means of a pump until the steam gage indicates the test pressure. The pump should only deliver a small quantity of water at each stroke, and must be worked carefully as the pressure rises, in order to avoid jarring the strained boiler, and producing a sudden rise of pressure beyond the limit of test pressure. Some engineers close the safety valve before the boiler is quite full of water, and so retain a quantity of air to act as a cushion when the pressure is applied by the pump; but the objection to the enclosed air is, that when it escapes through leaky seams and rivets no marks indicating such leaks are produced on the plates. When boilers are tested by hydrostatic pressure the water should always be hot, or at least warm.

47. Q.—What is a "fire crack" in a boiler?

A.—The failure of iron fireboxes is generally caused by blistering; the failure of steel fireboxes is generally caused by cracking; hence we may define the term "fire crack" as a separation of two parts of a *steel* firebox sheet, with or without a noticeable space between them.

48. Q.—Will one-fifth less than the area of all flues in an upright boiler be correct for the area of the smokestack?

A.—The cross-sectional area of the smokestack should be one-eighth of the area of the grate surface.

49. Q.—How high up on the tubes should the heating surface in an upright boiler be taken?

A.—Up to the water line.

50. Q.—In computing the heating surface of tubes do you take the outer or inner surface?

A.—We always take the outer surface. Some engineers insist that the inner surface should be taken.

51. Q.—Would you recommend cast iron or flanged steel for heads of boilers?

A.—Flanged steel; cast iron should be avoided as much as possible for vessels subjected to a steam pressure.

52. Q.—How is the horse-power of a boiler computed? Also, how are the heating surfaces in locomotive boilers and tubular boilers set in brickwork computed?

A.—The heating surface in all kinds of boilers is made up of the plates or portions of plates which come in contact with

the water one side and heat on the other side of the plate; hence the heating surface is computed by finding the area in square feet of each plate or portions of a plate which constitute the heating surfaces as stated above; the sum of these areas will be the required heating surface. These areas are found by the simplest rules of mensuration. If it is a rectangular plate, we simply multiply the length and breadth in feet of its surface, or that portion of the plate which constitutes the heating surface. In computing the heating surface of tubes it is customary to take the outer surface of the tube, because the size of tubes is generally given by the diameter of the outer surface, and seldom contains inconvenient fractions; hence to find the heating surface of the tubes, multiply the outer circumference of a tube in feet by the length in feet between tube sheets and by the number of tubes; the result will be the heating surface of the tubes in square feet. The term "horse-power of a boiler" is a very indefinite one, and then, again, the rate of evaporation per square foot of heating surface for different kinds of boilers varies within such wide limits as to practically render worthless the rules bearing on the subject. But since it is convenient for boiler makers to have some means of rating the horse-power of boilers, the following proportions are frequently adopted: Water-tube boilers, 10 to 12 square feet; tubular boilers, 14 to 18 square feet; flue boilers, 8 to 12 square feet; plain cylinder boilers, 6 to 10 square feet; locomotive boilers, from 12 to 16 square feet, and vertical tubular boilers, 15 to 20 square feet of heating surface per horse-power. It is, however, far more satisfactory to rate the boiler by the amount of water evaporated per hour. The standard adopted by the American Society of Mechanical Engineers is 34½ pounds of water evaporated from and at 212 degrees per hour.

53. Q.—What thickness of steel should be used for firebox patches?

A.—We should use the same thickness of steel as is used in the firebox.

54. Q.—How much lap is allowed, and where are the center lines of holes for rivets or bolts relative to lap?

A.—The center lines of the holes are in the center of the lap. The ordinary practical rule for determining the amount of lap is to make the distance from the center line of rivets to the edge of plate equal to 1½ times the diameter of the rivet; for thin

plates up to ½ inch thick, we would recommend for this distance 1⅝ times the diameter of the rivet for iron and steel plates.

55. Q.—What size of rivets or patch bolts are used, and which is preferable, rivets or patch bolts, and why?

A.—Diameter of rivets for plates ¼ inch thick, 9-16 inch; for plates 5-16 inch thick, 11-16 inch diameter, and for plates ⅜ inch thick, ¾ inch diameter. We prefer rivets, but in some cases it may be impossible to use rivets; under these conditions patch bolts will have to be used.

56. Q.—What style of patch—straight, dished with projections towards the fire, or dished with projections towards the water space—is the best?

A.—We should not dish the patches; if the sheets to which they are applied are straight, then make the patches straight; if the sheets are curved, then give the patches the same curve. We prefer to put the patches in the water space; the advantage of this is that the stress on the bolts or the rivets will be much reduced. There is, however, a disadvantage in placing the patches inside of the water space, namely, it will be difficult to calk them, if not impossible. In all cases the boiler makers must use good judgment, and place the patches so as to prevent them from collecting mud, and put them in the best positions as conditions may allow.

57. Q.—To what depth should the holes for rivets or patch bolts be countersunk, and what bevel is recommended for the heads of the patch bolts?

A.—The countersink should extend to a depth of one-third of the thickness of the sheet. For a ¾-inch bolt the diameter of the countersink should be 1½ inches; for other sizes of bolts make the degree of bevel proportional to the above figures.

58. Q.—Give rule for finding the number of flues which can be placed in a circular boiler head—a rule that will apply to all sizes of flues and spaces.

A.—The graphical method is the best one for the solution of problems of this kind. On a sheet of paper draw the center lines of the tubes, and on these center lines lay a sheet of tracing paper with the circumference of the boiler head drawn upon it. In this way you can determine at once the number of flues which can be placed in the head.

59. Q.—Tensile tests of materials in testing machines strain the test piece in one direction only, while in actual boilers the strain is applied in two directions, and a correspondent wishes to know if the results obtained on the testing machine are strictly applicable to the conditions found in boiler work.

A.—Experiments have been made on pieces under stress in two directions at right angles to one another, as the strains are applied in actual boilers, and the results show that the smaller strain does not affect the strength of the piece in the direction of the larger strain.

60. Q.—What is the way to find the safe working pressure per square inch of a steam boiler?

A.—The rule given by the Board of Supervising Inspectors of Steam Vessels is as follows: Multiply one-sixth of the lowest tensile strength found stamped on any plate in the cylindrical shell by the thickness in inches of the thinnest plate in the same cylindrical shell, and divide the product by the radius in inches; the result will be the pressure allowable per square inch for single riveting, to which add 20 per cent. for double riveting.

61. Q.—If, when the water pressure is applied to the boiler, the safety valve begins to discharge at the pressure for which it is set, is that a sufficient proof that the safety valve is all right?

A.—It is necessary that the safety valve not only opens at the predetermined pressure, but that it open enough to discharge a sufficient volume of steam, and this cannot be proved by the flow of water alone.

62. Q.—A claims that the heating surface of a steam boiler is every square inch of that which is touched by fire or gas on one side and by water on the other. B claims that the heating surface is every square inch of that surface which is exposed to the fire and hot gases.

A.—The heating surface in boilers is that surface which transmits heat to the water; hence it is the surface which is in contact with the water on one side and exposed to the heat on the other side. According to the foregoing, A is right. The heating surface is generally given in square feet, and not square inches.

63. Q.—Why can the tubes in a vertical boiler be partially exposed to the heat from the furnace, while in horizontal boilers they must always be covered?

A.—In upright boilers that part of the tubes nearest the fire is covered with water, and the heat is taken up so quickly that by the time the gases get above the water line they are not hot enough to do serious damage.

64. Q.—I have a horizontal tubular boiler, in use about one year. It was sold to me for 100 horse-power. How much water should this boiler evaporate to be 100 horse-power? The steam pressure varies between 60 and 80 pounds.

A.—Assuming the average pressure to be 70 pounds, the boiler should evaporate 3,000 pounds of water per hour, with feed at about ordinary temperature.

65. Q.—When a boiler is sold to evaporate a given amount of water per hour, what is understood, and how is the matter come at?

A.—It would be understood that the evaporation should be from and at 212 degrees. That is the same as if the water were supplied to the boiler at 212 degrees and the steam allowed to pass to the atmosphere without hindrance, the location being where water boils at 212 degrees. In practice the water is supplied at any temperature and any desired pressure is maintained. Then the heat required to raise the water from the temperature of the feed to 212 degrees, and the extra heat required to vaporize it under the higher pressure are found by consulting steam tables, and in this way evaporation that would have been from and at 212 degrees is calculated.

66. Q.—How can I tell whether or not the steam from my boiler is dry?

A.—The only way you can determine this with certainty is to get an engineer used to such matters to make a calorimeter test for you. If you place a small cock—say ¼-inch—in the steam pipe close to the boiler, an experienced engineer can tell very closely by opening it.

67. Q.—From such tests as my engineer has been able to make, weighing his coal and water used for ten hours, he calculates that the boiler evaporates 9¼ pounds of water per pound of good coal used. Now, I am approached by the agent for a patent boiler, who agrees to sell me a boiler that will evaporate 12½ pounds of water, and on this basis he says it will pay me to throw out my old boiler and put in his. The present boiler works satisfactorily in every way. My engineer quotes "Let well enough alone" to me. What do you think of it?

A.—If your boiler is evaporating 9¼ pounds of water per pound of coal, and is, as you say, satisfactory in other respects, we think your engineer is a sensible man. We do not believe there is a boiler in the United States that is evaporating 12½ pounds of water per pound of coal. We have sometimes read of such performances, but never saw anything approaching it very closely.

68. Q.—Can I save anything by burning a cheap quality of coal; and, if so, what will the saving be?

A.—If your boiler will make all the steam you want with the cheap coal, you may probably effect some saving by using it. The only way to determine this is by a trial of a week or two. We cannot say what the saving, if any, will be. "Cheap coal" is decidedly indefinite, and we could not tell if we knew all about the difference in price.

69. Q.—In tubular boilers what do you consider to be the best ratio of heating surface to grate area for anthracite coal, for good bituminous coal, and for wood?

A.—For all these we should allow about 30 square feet of heating surface to 1 square foot of grate surface, although for anthracite coal this ratio may be somewhat reduced, because the depth of hard coal fires is less than that of soft coal fires, and in order to evaporate the same amount of water with a given amount of coal in both cases the grate area for anthracite coal burners must be increased, which will allow a slight decrease in the ratio of heating to grate surface.

70. Q.—What is the best ratio of total tube area to grate area?

A.—The total tube area should be about one-eighth of the grate area.

71. Q.—How many square feet of grate surface should be allowed per nominal horse-power?

A.—The term nominal horse-power has no meaning, and, therefore, cannot be used for proportioning the grate surface; the latter depends on the kind and quality of fuel to be used.

72. Q.—With good natural draft, how much anthracite coal and how much bituminous coal should be burned per hour per square foot of grate surface?

A.—Of anthracite coal about 12 pounds; of bituminous coal about 16 pounds. These quantities refer to the average quality of coal.

73. Q.—How much water should be evaporated per pound of anthracite, and how much per pound of bituminous coal?

A.—Since both kinds of coal contain nearly the same units of heat, each kind should evaporate about 10 pounds of water per pound of coal with ordinary firing.

74. Q.—What percentage in area would you make that of the smoke flue exceed the total tube area?

A.—That depends upon the size of the boiler; generally for large boilers the area of smoke flue does not exceed that of the tubes; for smaller boilers it is usually a little greater.

75. Q.—Please define the term "specific volume of steam."

A.—By specific volume is meant the volume of one unit weight of steam (one pound or one kilogram) for a given temperature and pressure.

76. Q.—How many pounds of good seasoned wood are equal to a pound of coal?

A.—About 2½ pounds. Weight for weight, there is little difference in the heating value of different woods. It is important that the wood be dry.

77. Q.—How many cubic feet of natural gas are equal to 1 pound of coal?

A.—About 15.

78. Q.—I would like to have you give me a rule for computing the length of a safety valve lever when the weight, steam pressure, size of valve and the distance from the fulcrum to the valve are given.

A.—Multiply the steam pressure per square inch by the area of the valve in square inches and by the distance in inches from the center of valve to the fulcrum; call this product 1. Multiply the weight of the valve and spindle by the distance from the center of valve to the fulcrum; call this product 2. Multiply the weight of the lever by the distance in inches from the center of gravity of the lever to the fulcrum; call this product 3. If the lever has the same depth and thickness throughout its length, the center of gravity will be in the center of the lever; if the depth or thickness decreases towards the end, find the center of gravity by balancing the lever on a knife's edge. From product 1 subtract products 2 and 3, and divide the remainder by the weight to be placed on the end of the lever; the result will be distance in inches from the center of weight to the fulcrum.

79. Q.—Instead of a lever and weight on a safety valve, the weight is placed directly on the valve. How can I find the pressure of steam per square inch that will lift the valve?

A.—Divide the total weight of ball and valve in pounds by the area of the valve in square inches exposed to the action of the steam in boiler; the quotient will be the steam pressure per square inch which will just balance the weight of valve and ball; any increase of the steam pressure, however small, will lift the valve. In this case it is assumed that there is no friction. An arrangement of this kind is dangerous, as the weight may cant the valve to one side, causing considerable friction between the valve and the aperture, and thus prevent the valve from lifting and acting as it should do.

80. Q.—If the total weight of valve and ball placed on top of the valve is 80 pounds, and the area of the valve 7 square inches, what pressure of steam per square inch will lift the valve?

A.—$80 \div 7 = 11.42 +$ pounds per square inch of valve.

81. Q.—What is the difference between the foaming and priming of a boiler, and what are the causes?

A.—Foaming is caused by the presence of oil, dirt, or other foreign matter in the boiler; priming is caused by having an insufficient steam room in the boiler. When the latter is the case the boiler, when in use, will prime continually and is detected by the continuous fluctuation of the water in the water-glass gage; whereas foaming will occur only at intervals, and is also detected by occasional similar fluctuations of water in the glass.

82. Q.—Why is it that changing the water in a boiler from hard to soft seems to loosen the scale?

A.—To answer this question correctly an analysis of the two kinds of water would have to be made. But, on general principles, it may be said that the soft water referred to has no scale-making properties, and will in time loosen the scale previously formed by the hard water, pure water being nearly a universal solvent.

83. Q.—How much soda shall I put in a boiler, 4½ by 16 feet, to remove grease which finds its way in by exhausting into an open well from which the feed water is taken? Will it injure the iron?

A.—You can use from four to five pounds at a time. No.

84. Q.—I want to use soda (carbonate) in my boilers to remove the scale, but I don't know that it is generally used. How often and how much at a time should I use? The boiler is 16 feet long and 4 feet diameter; it is made of steel. The water due to condensation is returned to the boiler. We heat with the exhaust steam.

A.—Carbonate of soda is frequently used for removing scale. It is recommended, if the boiler is badly scaled and if it can be spared from use, to put in a quantity, say one pound for each horse-power, and keep the boiler under steam, say 40 to 50 pounds' pressure, and let it remain so for 24 hours, and then wash out. If this don't answer try another dose. The amount of soda to be used daily will depend upon the quality of the water, and must be determined by your own good judgment. Start with about 2 pounds per 24 hours, and gradually increase the dose, if necessary; or decrease the dose if it causes the boiler to foam.

85. Q.—Caustic soda is said to be very efficient for preventing scale in boilers. I should feel greatly obliged for information in regard to it. Does it damage or corrode the water plates? If not, what should be the quantity used?

A.—No damage will result if used with care. The usual quantity varies from ½ pound to 2 pounds per day, according to the quality and quantity of the water evaporated. We should advise you to have the water analyzed, which may show that other chemical agents will answer your purpose better.

86. Q.—If the water begins to fluctuate in the glass gage, and I am afraid that it does the same in the gage cocks, how can I tell with certainty where it is?

A.—Shut your damper and shut off all flow of steam from the boiler, and the water will settle to its true level.

87. Q.—What is the cause of bubbles rising from the bottom of my water glass, running rapidly to the top of water level, and sometimes carrying the water clear to the top of the glass? This occurs while the engine is running. Steam pressure in the boiler is 80 pounds.

A.—It seems to us that your boiler is priming; the probable cause is that the steam space in the boiler is too small, or the water carried too high. Priming may also be caused by forcing the boiler to do a greater duty than it was designed for. What-

ever may be the cause, it is a dangerous occurrence and should be overcome at any cost.

88. Q.—In a book I have on the care of engines and boilers I find something I am not able to see clearly. I refer to the instructions in the case of low water. These are explicit as to the fire, but nothing is said about the water. I was recently called in to look after a boiler where the engineer had absented himself, regardless of water or fire. It was a tubular boiler, and the steam was so low that the engine had stopped. I tried the stop cock in the glass gage and found the water about level with the lower cock. The feed water was warm, so I started the pump (there was steam enough to just keep it going) till the glass showed 2 inches of water. I then commenced firing till I got steam enough to start the pump again. What I want to know is, did I do right, and what should I do if the water was below the tubes?

A.—We infer that you satisfied yourself that the water was not below the tubes, in which case you did right to pump slowly. If the water is below the tubes, haul the fire or cover it up with coal and ashes, so that no heat can come from it, and change nothing whatever around the boiler; that is, if the engine is running, or steam being drawn from the boiler for any purpose, let it continue. If steam is shut off, let it remain so, and wait for the boiler to cool down. Having prevented further heat from coming to the boiler, you have done all you can do with safety in the instance of water below the heating surface.

89. Q.—We have a 3-inch flange union between two boilers, and the packing is constantly burning out. Is there anything for packing this union better than sheet lead?

A.—We should consider sheet lead about as near worthless for the purpose named as anything that could be used. Asbestos packing, which you can get from dealers in such supplies, will probably be entirely satisfactory. Rubber, or drawing paper soaked in linseed oil, is better than the lead.

90. Q.—If a flue should burst and let the water and steam out of the boiler, how would you fill the boiler by the injector?

A.—We should first put in a new flue, or, if the flue is of a comparatively small diameter and it cannot be obtained in time, we should plug up the flue holes. If, then, a boiler under steam pressure is near at hand, we should take steam from this boiler

to the injector and fill the boiler in the usual way. If steam cannot be obtained in this way, the boiler cannot be filled with the injector, as the latter cannot be made to work without steam.

91. Q.—We have shut down two 90 horse-power boilers, and would like to know of a good way to keep them from rusting. Shall I fill them with water?

A.—When a boiler is to be taken out of service do not blow out the water by the pressure of the steam; the water must be allowed to remain in the boiler until it is cool, and then permitted to run out through the hand hole and blow-off cock; after this clean the boiler thoroughly. There are several ways of preventing the boiler from rusting. One way is to refill the boiler gradually, after it has been cleaned, with warm water, care being taken that the boiler is also warm before refilling, so as to avoid the danger of unequal expansion; if cold water is used, a light fire should be kindled in the furnace after refilling, so as to heat the water. When nearly full one or two gallons of crude oil should be put in the boiler, after which the water is permitted to run out slowly through the bottom blow-off cock. The oil which floats on the top of the water will adhere to the inner surface of the boiler as the water level is lowered. When the boiler is empty close it up tight. Another way is to clean and dry the boiler thoroughly, and to protect it from moistures, a light fire of shavings should be kindled in the ash pit about once a week. Some engineers fill the boiler quite full of water and close up tight.

92. Q.—Two boilers furnish steam for two compound condensing engines. One quart of a cheap, well-known cylinder oil goes through each engine in 12 hours, and the water and oil from the condenser is pumped back into the boilers. All the rivets, joints and flue ends in the boiler leak considerable at times. What is the cause of the trouble?

A.—To return oil into the boilers is very bad practice, and can be avoided by the use of a separator placed between the engine and boiler. Oil in boilers will sometimes cause pitting; but it is doubtful if the oil is the whole cause of the leakage. The acids in the water and the quality of the iron may also be the cause of the trouble. The water in some localities, while but slightly acting upon the body of the plates, attacks the rivet

heads or edges of the plate and angle irons. Sometimes it happens that it is mainly the transverse seam rivet heads and plate edges that are attacked, and sometimes the longitudinal seams.

93. Q.—What is the cause of excessive corrosion in a boiler which supplies steam to a condensing engine; steam pressure 100 pounds? The feed water is filtered through coke and returned to tank. The supply of water is taken from a pond formed by surface drainage of wooded land.

A.—The corrosion is due to the impurities in the feed water, and to the free acids so often found in the purest waters used for boiler feeding. Common soda has the power of neutralizing the free acids and impurities, and therefore the introduction of about half a pound of common soda per day into an ordinary large-sized boiler is generally found sufficient to prevent, or at least to greatly mitigate, any corrosive action. When grease is present in the water the foaming up of the water is increased by the addition of soda, and if this is allowed to take place to any great extent trouble by priming is liable to ensue. To prevent this a surface blow-out should be used. The best way, however, to pursue is to have the water analyzed, which will, no doubt, suggest a remedy.

94. Q.—In using petroleum in a boiler for the prevention of scale, can the hydrogen which may be liberated in any manner become ignited without any outside agencies acting upon it, and thus cause an explosion of the boiler?

A.—No. But explosions may result from the use of crude petroleum, if not used cautiously; this oil is very heavy, and when mixed with mud will form a paste, and if this settles on the crown sheet of a boiler the sheet may be burned, which may cause a serious explosion. The use of kerosene is much safer; there is not a sufficient body in this oil to form a paste, and it will not stick fast to the interior of a boiler.

95. Q.—I have a drum, 6 feet long and 3 feet diameter, set on end, with a pipe connection through the bottom to a first-class suction pump in good order, pumping into a boiler against a steam pressure of 75 pounds. The drum is half full of water, and the upper half is nearly a vacuum. The pump sets below the drum. Can I pump the water out of the drum into the boiler under these conditions?

A.—Yes.

96. Q.—Is a steam jet in the smokestack injurious to a marine boiler?
A.—No.

97. Q.—My idea of a steam jet is that it forms a vacuum in the stack, and the surrounding atmosphere is forced in by its own weight. Am I right?

A.—The steam jet gives an upward current to the air, thereby reducing the density of the gases below that of the air outside, which, on account of its greater weight or pressure, flows into the furnace.

98. Q.—Has kerosene or common black oil a tendency to cause foaming in a boiler? Also, what is best to use for loosening the scale in a common 12 horse-power boiler, and how can foaming be prevented?

A.—Kerosene, used in moderate quantities, will not make the boiler foam; it is recommended and used for loosening the scale and for preventing the formation of scale. Neither will a small quantity of common oil always cause foaming. It is sometimes injected into small vertical boilers to prevent priming, and is supposed to have the same effect on the disturbed surface of the water that oil has when poured on the rough sea. Yet oil in boilers will not have the same effect and give the desired results in all cases, as practice has shown beyond dispute that the presence of oil in combination with other impurities increases the tendency of many boilers to foam, as the oil with the impurities impedes the free escape of steam from the water surface. The use of common oil not only tends to cause foaming, but is dangerous otherwise. The grease appears to combine with the impurities of the water, and when the boiler is at rest this compound sinks to the plates and clings to them in a loose, spongy mass, preventing the water from coming into contact with the plates, and thereby producing overheating, which may lead to an explosion. It may be said that this spongy mass acts similar to water thickened with oatmeal, which, if we attempt to boil it without stirring, will cause the bottom of the kettle to be overheated. Foaming may also be caused by forcing the fire, or by taking the steam from a point over the furnace or where the ebullition is violent; the greasy and dirty state of new boilers is another good cause for foaming. On the other hand, kerosene is not so liable to combine with the impurities in the water,

and is known to attack and remove the scale. Its use for removing scale may therefore be recommended; but it should be used at first in small quantities; the effect should be carefully noted, and the quantity increased if necessary for obtaining the desired results. Since we have given the cause of foaming, it will readily be seen what should be done to prevent it.

99. Q.—I would like to know how to take care of a steam boiler. Is there any preparation that will keep the boiler from rusting inside? I have a boiler which is not used continually, and consequently it has a chance to rust. I use clean rainwater.

A.—When the boiler is to be taken out of service do not blow out the water by the pressure of the steam. The water must be allowed to remain in the boiler until it is cold, and then permitted to run out through the hand hole and blow-off cock; after this clean the boiler thoroughly. There are several ways of preventing the boiler from rusting. One way is to refill the boiler gradually, after it has been cleaned, with warm water, care being taken that the boiler is also warm before refilling, so as to avoid the danger of unequal expansion; if cold water is used a light fire should be kindled in the furnace after the refilling, so as to heat the water. When nearly full, one or two gallons of crude oil should be put in the boiler, after which the water is permitted to run out slowly through the bottom blow-off cock. The oil which floats on top of the water will adhere to the inner surface of the boiler as the water level is lowered. When the boiler is empty close it up tight. Another way is to clean and dry the boiler thoroughly, and to protect it from moisture a light fire of shavings should be kindled in the ashpit about once a week. Some engineers fill the boiler quite full of water and close up tight.

100. Q.—Would you give us the formula for making a rust joint with cast-iron borings that will stand steam heat?

A.—Rust steam joints are usually made with sifted cast-iron borings or turnings, sal-ammoniac and a little sulphur, mixed to a rather stiff paste with water and packed into the joint with a chisel or calking tool. One part sal-ammoniac, two of flowers of sulphur and eighty of iron borings or turnings, by weight, is given for quick setting; and one sal-ammoniac, one-half sulphur and one hundred of iron for slow setting.

101. Q.—Can hot water be pumped into a boiler carrying 60 pounds steam pressure? The water is taken from a 1-inch coil heater; the pump used is a horizontal plunger pump; check valve is straight.

A.—The pump will force hot water into the boiler, providing the heater is placed somewhat above the pump, so that the water can flow to the pump. If the heater is placed below the pump you will experience great trouble in the suction, because pumps cannot lift water having a high temperature.

102. Q.—Is water containing a strong solution of sulphur injurious to a boiler, and, if so, in what manner?

A.—Sulphur is not found in solution in water, except in combination with another element. Its most common condition in water is as sulphate of lime, when it injures the boiler by scaling. In some places, especially in mining regions, sulphur contaminates water in the form of sulphate of iron, when it has a corrosive action on boilers.

103. Q.—Is it safe to blow down the water in the boiler to the lower gage cock while the engine is running?

A.—That depends upon where the lower gage cock is located. Generally this cock is placed so that there is no danger of burning the boiler so long as water shows at it, in which case there would be no danger in blowing down to it, provided your pump is all right, and will more than supply the boiler. One of the first things an engineer should find out is if there is water on the heating surfaces of the boiler when the water is down to the lowest gage.

104. Q.—I notice an engineer who, when he banks his fire, closes the ashpit and fire doors and opens the flue doors and damper. My plan is to close the ashpit doors, leave the flue doors closed, and if any doors are open, let it be the fire doors—a little. Which plan is the best?

A.—Yours. It is wrong to open the flue doors.

105. Q.—Does an injector deliver less water when working against a pressure higher than that in the boiler from which steam is supplied?

A.—Wm. Sellers replies as follows: "An injector having a fixed area of water inlet will deliver the same quantity of water into the air against no pressure (by gage), or into a boiler at any

pressure against which the injector is capable of working without overflowing, in each case the steam pressure and area of steam and water inlet remaining unchanged."

106. Q.—How much water can be obtained from any kind of evaporator?

A.—The amount of water which can be obtained from an evaporator depends on the temperature of steam and the construction of the evaporator; a formula which covers all cases cannot be given. For a rough approximation you may assume that one square foot of heating surface will evaporate 1½ pounds of water per hour.

107. Q.—Is there sufficient advantage in a round chimney over a square one to recommend a somewhat expensive change?

A.—There is very little difference between a square and round chimney as far as draft is concerned. Square chimneys of moderate cross section are cheaper to build.

108. Q.—Is it practical to attach the steam gage to the steam pipe when it cannot be attached to the boiler so as to be readily seen? In our case the steam gage was put on the steam pipe in the engine room. D says that this is not safe; I claim that it is practical and just as safe.

A.—You are decidedly wrong. It is not safe to have the steam gage attached to the steam pipes without having another one on the boiler. The steam gage pipe should be attached to the top of the dome or drum, and the steam gage placed in some convenient position so that it can be consulted every few minutes. The sooner you have this done the better.

109. Q.—I ordered a set of boiler tubes, 2¾ diameter, 16 feet long, from a hardware house. I cut each into three pieces of equal lengths. After getting them in my boiler I find them too hard to work—the bead will break off all around. I sent them back to the hardware house, and was informed that I should anneal them. I think that they should be annealed in the factory, as I am of the opinion that I cannot anneal them properly in the open air, and they should be annealed in a furnace in the tube factory. Please state whether I am right or wrong.

A.—If your order called for annealed tubes, and the dealer sent you another kind, he should replace them by the kind ordered. If the order did not call for annealed tubes, you will

have to anneal them or pay for having it done. Although it is best to anneal the tubes in a furnace, you can, for the purpose of expanding the tubes, heat the ends in a blacksmith's fire and let them cool slowly in lime.

110. Q.—I have a tank which receives the water due to condensation; the steam pressure is sometimes as high as 75 to 80 pounds. I want to pump this water and steam into the boiler, but the pump which I have gives me trouble in keeping it packed and in other ways. Please inform me through your columns what kind of pump is best adapted for this purpose.

A.—Nearly all manufacturers make a special pump for this purpose. These pumps are usually operated by a hollow float in the tank and by means of intermediate connections. When the float rises the pump is started, and the speed is regulated according to the quantity of water flowing into the tank. The pump slows down as the supply of water drops off, and when it ceases the pump stops entirely. By writing to any one of the prominent manufacturers of pumps you will undoubtedly get one that will answer your purpose and work satisfactorily.

111. Q.—Is it proper to use the word stack when speaking of the chimney of a locomotive or portable engine, or should it be used only when speaking of several chimneys together?

A.—Common usage makes it proper to apply the word stack to a single chimney. One of Webster's definitions of the word is: "A single passageway for smoke; the chimney of a locomotive or steam vessel."

112. Q.—What is the duty of a back pressure valve, and what is the duty of an equalizing valve?

A.—When the exhaust steam from an engine is used for heating or other purposes a back pressure valve is used; the duty of valves of this kind is to prevent the back pressure in the engine cylinder exceeding given limits. The duty of equalizing valves is to equalize the pressure in two given vessels.

113. Q.—What is the rule for computing the velocity of steam flowing through an orifice in a boiler, pressure of steam being given?

A.—Steam of any pressure flowing through an opening into any other pressure less than three-fifths of the initial has practically a constant velocity of 888 feet per second.

114. Q.—I am using a National feed water heater, which condenses the

steam, giving me about a 1-inch stream. I want to pump that water back to the boilers. Would it cause the boilers to foam, or would it be injurious in any way?

A.—The water will be all right if the oil is extracted. Pass it through a horizontal box, say 2 feet square and 10 feet long, and filled with "excelsior." The excelsior must be renewed occasionally. Hay or straw may be used instead, but the excelsior is to be preferred.

115. Q.—In steam fitting, which is the proper way to place a valve—with the steam pressure tending to hold the valve on its seat or tending to assist the opening of the valve?

A.—Assuming the question to refer to the familiar globe valve, we would say that it should be placed so that the steam pressure would come under the valve. When the steam was shut off the stuffing box would then be relieved of pressure, and, if necessary, it would always be possible to repack the stuffing box; while with the steam above the valve, it could not be done. It is also much easier to open the valve; and if the opening required is small, it is easier to adjust it if the pressure is under the valve. With the pressure above the valve it is difficult to adjust the opening very fine, as the slack of the valve on the spindle allows it to jump a little one way or the other; while with the pressure under the valve the slack or lost motion is always taken up by the steam pressure.

116. Q.—What is saturation, and what is it on the salinometer scale?

A.—The saturation point is reached when the liquid contains all the salt that it can hold in solution. The graduation upon the salinometers for marine use do not extend to the saturation point. Sea water contains by weight 3.39 parts of salts in solution of 100. It is saturated when it contains 36.37 parts to the 100.

117. Q.—What is the degree of saltness or saturation in a marine boiler?

A.—This question must refer to the permissible saltness in marine boilers, as it must, of course, never approach the actual saturation point. The salinometer registers 0° for pure water and 10° for sea water; and with jet condensers and feeding only sea water the water in the boilers should not be allowed to go beyond 30°. The amount of salt deposited on the surface of the

boiler does not depend on the density of the water, but only on the quantity of sea water pumped into the boiler. It is said that the boiler of a surface condensing engine may be worked with perfect safety and with economy when the water is four times as salt as sea water, or when the naval hydrometer registers 40°. The Boiler Committee of the British Admiralty appointed in 1873 recommended that the boilers of surface condensing engines be worked at 45°, and those of jet condensing engines at 35°.

118. Q.—In connecting several boilers to a flue leading to a chimney how is the area of flue determined?

A.—If the chimney area is correct the areas of the flues may be proportioned from that. The proper starting point, however, is with the grate. Professor Thurston says: The minimum ratio of chimney flue section, section through the tubes and that over the bridge wall to grate surface should be at least, respectively, 1-9, 1-8, 1-7. The flues, if leading from different boilers, should, of course, at any point be proportioned to the number of boilers in communication. The progressive cooling of the gases calls for a slight gradual reduction of area towards the chimney to secure a uniform rate of flow.

119. Q.—S says he has trouble with the feed pipe of his boiler. It is located at the back end of the boiler in the combustion chamber, and gives trouble by burning off. He proposes to enter it at the front end over the fire doors, and asks if this is considered a proper place. The boiler has no mud drum.

A.—It is not safe to introduce cold feed water right over the fire, as our correspondent proposes to do. The plan advocated by the Hartford Steam Boiler Inspection and Insurance Company is to enter the feed pipe through the front end and at one side and above the tubes. The pipe is then carried inside the entire length of the boiler to the back end, where it crosses over and turns downward, discharging the water (which by this time will have become well heated) between the tubes and shell. The blow-off should be located where the feed now is, and, unless protected, will give trouble from the same cause. A cast-iron sleeve will make a good protector, which, to provide for easy renewal, should be in halves.

120. Q.—What is the proper area for a safety valve? Should it equal the area of the feed pipe?

A.—Safety valve areas are computed rather from grate bar than from feed pipe data, although both have to do with the generation of the steam which the safety valve is expected to discharge. The rule of the United States Supervising Inspectors of Steam Vessels requires with lever valves 1 square inch of safety valve area for each 2 square feet of grate surface, and for spring or "pop" valves 1 square inch of area to 3 square feet of grate surface.

121. Q.—Which will dry a piece of wet cloth the sooner, a cylinder made of sheet copper 1-16 inch thick or a cylinder made of sheet steel the same thickness, both cylinders being steam tight and heated by steam at the same temperature? The cloth is laid on the cylinder body.

A.—While the conductivity of copper is more than double that of steel, there would be probably little appreciable difference in drying effect with the two metals; the rate of evaporation would be determined by the ability of the cloth and its contained moisture to absorb the heat, rather than by the ability of the metal to convey the heat. The condition of the surfaces of the two metals would be an important factor. The steel surface should be free from scale or oxide, or the copper would have an advantage on that account.

122. Q.—I have a drying room 6x8x15 feet; I wish to raise its temperature by means of steam to 300 degrees. What pressure of steam will I require, and what size and how many feet of pipe will be needed? The floor, top and sides are made of brick laid to a thickness of 9 inches; one end has two large iron doors.

A.—The amount of pipe will depend much on the time during which the temperature has to be raised to 300 degrees. On general principles, we should say put in as many feet of 2-inch pipe as you can conveniently place along the sides and one end of the room. Make provisions for draining the water from the steam pipes. You will require a steam pressure of about 75 pounds (gage pressure).

123. Q.—Please name the best paint for a smokestack to prevent rust. We now use coal tar, but it does not last very long.

A.—Ground graphite mixed with the coal tar, and the mixture thinned with turpentine may give you better results. Dixon's graphite paint has a good reputation.

124. Q.—Is a steam gage light or heavy when it shows 10 pounds, with no steam on, and how will it be at 50 pounds?

A.—We should say it was light at 10 pounds, but cannot say how it will be at 50 pounds.

125. Q.—I have a feed pipe so arranged that I can pump either into two boilers at the same time, or into either separately. If the pressure is equal in both boilers what will be the difference in pressure against which the pump works between pumping into one or both boilers?

A.—If the pump is run at the same speed in both instances there will be no difference.

126. Q.—I have been constructing a mercury gage, made similar to a barometer, the upper end of the tube connected with the condenser. From what point shall I commence to graduate it?

A.—From the level of the mercury when the tube is disconnected from condenser.

127. Q.—I have a Richardson "pop" safety valve that leaked, and I have repaired it, making it tight; but now, when it blows off it reduces the pressure too much. What can I do to make the valve close after reducing the pressure about 5 pounds?

A.—The amount the valve will reduce the pressure is principally dependent on the distance the outer lip of the valve projects below the head of the bushing or seat and the extent of the opening between the inside surface of the lip and the head. In refitting the valve you have let the lip down lower than it was and diminished the opening, either of which will cause the valve to reduce the pressure more before closing. If you have one of these valves as at present constructed, by screwing up the screwed ring that forms the head of the valve you will, provided you have not got the parts out of truth in refitting, be able to make it blow down as little as you desire. If you have one of the old style, this can only be done by cutting a little off the lip and increasing the opening referred to. If you attempt this, you will have to work very carefully or you will go too far.

128. Q.—Is there anything in the line of a pencil for marking on iron which is better than the common slate pencil? Where can such be obtained?

A.—Some boiler makers prefer soapstone to the ordinary slate pencil. You can obtain it in any boiler makers' or tailors' supply store.

129. Q.—Is there any definite rule for placing the gage cocks on upright boilers? Does it make any material difference in regard to their position when the tube sheet is submerged?

A.—There is no definite rule. The general custom is to use three gage cocks for small boilers, placed about 2½ inches from center, measured in a vertical direction. In vertical boilers the hight of the water carried above the crown sheet is scarcely ever less than 12 inches; hence the lowest gage cock is generally placed from 10 to 15 inches above the crown sheet, according to the hight of the water to be carried. In some vertical boilers the whole length of the tubes is covered with water; in such cases the lowest gage cock is placed on, or one inch above, the lowest desired water line.

130. Q.—What is the benefit of a siphon on a steam gage? We are running one here with a straight pipe, and it seems to work all right.

A.—The object of the siphon, as it is called, is to prevent heating of the gage by steam getting into the tube. The lower part of the pipe fills with water condensed from the steam, and thus prevents the steam passing into the tube of the gage and heating it.

131. Q.—Which is the most economical, a crank and flywheel pump or an injector, both to take water at 60 degrees and force it through a heater to boiler?

A.—The injector used simply as a boiler feeder is more economical than a pump, because it heats the feed water; and the heat not expended as work in forcing the water into the boiler is returned to the boiler with the feed water. Economy may or may not be promoted in using the injector in conjunction with a heater, because the heat given to the water in passing through the injector may be thrown away; in such cases the injector has a low efficiency.

132. Q.—Which is the proper way to place a check valve on the feed pipe to a boiler? Should the check be between the boiler and globe valve, or should the globe valve be next to the boiler?

A.—The globe valve or its equivalent should be always placed next to the boiler and between the boiler and the check valve. In case anything then goes wrong with the check valve, such as leaking caused by a foreign substance getting into it, or if for

any reason it fails to seat properly, the globe valve can be closed and the check valve examined and repaired without letting steam or water out of the boiler. When a globe valve is used for this it is best to have one with a solid disk; that is, not loose on the stem, and a plug cock or gate valve is better than a globe valve.

133. Q.—What is the composition of metal for fusible plugs that are used in the crown sheets of firebox boilers; also the shape of the hole in the plug for receiving the metal?

A.—The plug is usually made of brass or composition, and screwed in water tight from the fire side of the sheet, with a taper hole through it for the fusible metal, the large end of the taper being towards the water, so that the pressure will not drive the metal out of the plug. The most reliable metal to use is probably pure tin. The alloys change in time, and are less reliable, although it is theoretically possible to make them to melt at almost any temperature above the boiling point. If the plug becomes covered with thick incrustation the metal may become hot enough to melt and run out, even with plenty of water above it. The melting point of tin is 442 degrees Fahr.

134. Q.—What is a good cement, or what will make a permanent joint, between two cast-iron plates? It must resist steam and water, say, up to 150 pounds pressure.

A.—Some engineers used for faced joints common drawing paper soaked in oil. After a short time the heat of steam converts it into a substance like parchment, so that it is practically indestructible. If the cast-iron plates are not faced, but are moderately true, a rubber joint may answer your purpose. If the plates are very rough, you may be compelled to drive a rust joint.

135. Q.—In most boilers, when under a good head of steam, the water rises in the glass, especially when the engine is started up. Now, what I wish to know is, from where does the water rise? Does it rise from the bottom? Or does it swell or expand in bulk? Or is there a space between the water and steam at a point below the glass? It seems to me that there is a dangerous spot somewhere in such boilers. I have not found a man that knew where the water came from.

A.—You can easily satisfy yourself on this point by trying

a simple experiment. Take a glass tube, closed at one end, or test tube, and fill about one-half of it with water, and hold it over a gas flame. As the water begins to boil bubbles of vapor will rise to the surface of the water; these bubbles require space, and consequently raise the water level. This is exactly what occurs when a boiler is crowded; the steam bubbles formed at the bottom require space, and raise the water level and carry some of the water upwards.

136. Q.—Is it correct to put a globe valve in a steam pipe, connecting the engine to the boiler, with the pressure on top of the valve? There is a gentleman here who claims to be quite a mechanic and says the pressure should be on top. I say it should be on the bottom of the valve. I have been thirty-nine years in the business, and I never put a valve in with the pressure on top, and I think I have the best of reasons for it.

A.—The pressure should be on top of the valve, so as to relieve the thread on the spindle of pressure as much as possible. The advantage of this is that when the valve is closed there will be no danger of its flying open, as might be the case when the pressure is on the bottom of the valve and the thread on spindle strip off. Particularly in a battery of boilers, we should always have the pressure on top of the valve, so that when one boiler is shut off for repairs and cleaning, while the other boilers are under pressure, the life of a man will not depend on the thread of the screw.

137. Q.—Why do engineers say 27 or 30 inches of vacuum, instead of pounds?

A.—The old-fashioned vacuum gage was composed of a U-shaped pipe, into which was poured a sufficient amount of mercury; one end of the pipe was connected to the condenser, while the other end was open to the atmospheric pressure, consequently when a vacuum is formed in the leg, between the mercury and condenser, the mercury column rises in the glass tube and indicates the amount in inches, which can be readily converted into pounds pressure, 2.04 inches of hight of mercury being equivalent to 1 pound. Although modern gages are differently constructed, the old nomenclature is still retained.

138. Q.—In putting up a water-feed pipe for a boiler, which of the two valves must be nearest the boiler, the stop valve or the check valve?

A.—A stop valve should in all cases be placed upon the feed pipe, and as close to the boiler as possible. The chief object being to cover all valves behind it, so that if anything happens to the check valve or any part of the pump, communication with the boiler can be shut off at once, allowing any necessary work to be done. We have known instances where the check valve has been next the boiler, but such an arrangement is considered bad workmanship, as the valve cannot be inspected should it become clogged or stuck.

139. Q.—What kind of grates are the best suited for burning sawdust?

A.—We have known excellent results obtained by using grate bars, made for ordinary purposes, of flat plates of a width of about 6 inches and running lengthwise of the furnace. Each of these plates has two ribs of a depth of about 4 inches by ½ inch thick, for supporting and preventing the plates from warping. The plates are perforated by holes ⅜ to 7-16 inch diameter, which are largest at the bottom, to facilitate molding and prevent the holes from stopping up. This style of grate has also been used for years upon locomotives for burning soft coal, and is adapted to burning coal dust, coke, and other miscellaneous fuels.

140. Q.—What will be the square feet of grate surface required, natural draft, to supply a cylinder 60 inches diameter by 11 feet stroke, 20 revolutions per minute, cut-off ⅝, working pressure 35 pounds, gage, and assuming a coal consumption of 15 pounds per square foot per hour? Please work this out from the volume of steam used in the cylinder.

A.—For the volume of steam used per hour we have 5^2 feet diameter of cylinder $\times$ .7854 $\times$ 22 feet per stroke $\times$ ⅝ cut-off $\times$ 20 revolutions per minute $\times$ 60 minutes = 323,977.5 cubic feet of steam per hour. To cover all contingencies, at least 50 per cent. should be added to this, which gives us 485,966.25 cubic feet. One cubic foot of steam at 35 pounds gage, or 50 pounds absolute pressure, weighs .1198 pound; so that our weight of water will be 485,966.25 cubic feet $\times$ .1198 = 58,198.75 pounds. Assuming 1 pound of coal to evaporate 8 pounds of water, and burning 15 pounds of coal per square foot of grate, 120 pounds of water will be evaporated per hour per square foot of grate. Then 58,198.75 $\div$ 120 = 485 square feet.

141. Q.—What do you mean by the area of a safety valve?

A.—The area in square inches of the opening in which the valve fits. For instance, if the hole is 4 inches the area of the valve would be $4'' \times 4'' \times 0.7854 = 12.56''$.

142. Q.—Steam passing through a short length of pipe freely into the atmosphere from a boiler in which the pressure is maintained at 100 pounds has a speed due to that pressure. What is the pressure per square inch exerted upon the wall of the pipe?

A.—At the entrance to the pipe the pressure would be equal to that in the boiler, less that due to the entry and velocity heads; at the discharge end the pressure would be that due to the velocity head at that point; at intermediate points the pressure would gradually reduce from one to the other. To attempt to reduce this statement to figures would lead to a very complicated expression, as the pressure would decrease and the velocity increase as the discharge end was approached. The first result would diminish and the second would increase the friction against the pipe. All of these factors would enter into the determination of the final velocity of discharge, which, again, would determine the velocity of entrance. We should expect an indeterminate equation as the result, which could only be solved by approximation. The condition of the steam as regards dryness would vary with the varying pressure along the pipe.

143. Q.—What are the rules for size and number of pipes for heating by exhaust steam on the overhead system? I desire to heat a foundry.

A.—The rules for the heating (outside) surface used by most engineers provide a certain ratio between this surface in square feet and the volume of the room in cubic feet. This ratio varies between 1 square foot to 50 cubic feet in the case of exposed rooms in isolated dwellings and 1 square foot to 200 cubic feet, or even more, in the case of churches, large halls, etc., a proportionately smaller amount of surface being required in large rooms. The character of the building must also be taken into account in deciding on the ratio, so that the rule of experience plays a large part. In your case, if your building is fairly well made, we should judge that a ratio of 1 to 100 would be sufficient. For exhaust steam the coils should be made of 1¼-inch pipe. By properly laying out the system, any ordinary shop

building may be heated by exhaust steam with almost no back pressure. We have not sufficient information to specify the exact plan, but do not have the coils arranged tandem, with the steam blowing through them in succession. Have several independent coils, with a branch pipe to each from the main exhaust. Do not use a barbarous back pressure valve, but put a gate valve in the main exhaust pipe, with the branches to coils between it and the engine, and then partially close this until steam blows from the outlets of the coils. In this way only so much steam goes through the coils as is necessary to fill them, the remainder going directly to the atmosphere. Do not put the coils too close to walls or ceiling, but allow sufficient space for free circulation of air. Provide an inclination of ¼ inch for each 10 feet of length for drainage. All coils should go around an angle to provide for expansion and contraction, and no unions should be used—close all coils with right and left couplings.

144. Q.—Which method is the more satisfactory when there is plenty of exhaust steam—to heat a building by live steam and return the water due to condensation to the boilers by trap, or to use exhaust steam from engine and not put the waste water in the boilers, but heating the feed water by exhaust steam in both cases?

A.—We should prefer to use the exhaust steam for heating the building.

145. Q.—Is there anything gained by using exhaust steam for heating purposes when it requires a back pressure on the engine to force it through the radiators? Is not the back pressure as much of an expense as live steam from the boiler?

A.—Although the back pressure may be increased in good working engines, say, a pound or two, when using the exhaust steam for heating purposes, there is still an economy in utilizing the exhaust steam, and the poorer the engine is, the greater will be the economy. This is true for all cases where there is use for the greater portion of the exhaust steam.

146. Q.—What are the heating qualities of exhaust steam as compared with live steam?

A.—The heat in ordinary steam is according to its pressure, whether it has passed through an engine or not. As a matter of fact, the greater part of the heat that is in the steam when it

leaves the boiler passes out with the exhaust from the cylinder, and can be most economically utilized for heating purposes.

147. Q.—Will a 3½-inch pipe flattened to ½ inch and to whatever width it will take, give the same result, either in efficiency or economy in heating at a low pressure, say 2 or 3 pounds, as it will when round?

A.—A round pipe of suitable size for the space it has to heat will be more efficient, because when round it will have a greater cross-sectional area than when flattened, and therefore the flow of the required amount of steam will not be checked, as will occur when the cross-sectional area is reduced by flattening. The economy will also be increased by using the round pipe because less weight of pipe will answer the purpose than is required with a flattened pipe.

148. Q.—Considering only the question of heating a shop, is it preferable to use steam about 75 pounds pressure, or at a lower pressure?

A.—A lower pressure is always preferable, say from 5 to 10 pounds, as such is safer and generally more economical than higher pressures.

149. Q.—How shall I compute the length of 1-inch pipe for heating a room 16x20 feet and 7 feet high?

A.—In computing the heating surface the kind of building must be taken into consideration; for a greater amount of heating surface will be required for a poorly put up than a well constructed one. The windows are the first and most considerable item; the kind of plaster on the walls, whether the building is exposed or sheltered, whether the whole house is to be heated, or only part of it, and what the building is used for, should receive due consideration. A rule for heating by steam frequently used is as follows: For direct radiating surface, add together the area of glass in the windows in square feet, the volume of air to be changed per minute and one-twentieth of the external wall and roof. Multiply the sum by the difference between the required temperature of the room and the minimum temperature of the external air; divide the product by the difference between the temperature of the steam in the pipes and the required temperature of the room. The quotient is the required radiating surface in square feet. The volume of air required to be

changed per minute is variously estimated from 3½ to 20 cubic feet per minute per head of inmates in ordinary good health. It seems to us that you will require about 40 square feet of heating surface. Assuming that each pipe is 2 feet long, 1¼ inches outside diameter, then its heating surface will be .65 square foot, and the number of pipes required $\frac{40}{.65} = 61$, making in all $61 \times 2 = 122$ feet of pipe.

150. Q.—Will a given quantity of steam passed through an engine, and then turned into a system of heating pipes, heat the building to the same degree as if led from the boilers directly into the pipes alone?

A.—The total heat left in the steam after passing through the engine will be equal to the original amount imparted by the boiler, less the heat equivalent of the work done in the engine (radiation losses while in engine will also, of course, reduce the final amount), and therefore the heating effect due to passing it on through the coils will be less—by the amount consumed—than if led directly from the boiler. The accepted theory of gaseous pressure is that it is due to the impact of the minute particles, this hypothesis having been found to explain most of the phenomena of unlimited expansion, etc., and a given weight of gas (steam or other) inclosed in a cylinder gives out, and therefore loses its kinetic energy to a moving piston in the same way that the energy of a blow is absorbed by a cushion or object moving away from the impact. Absolute temperature is a measure of the kinetic energy of a substance for each given state or condition, and the absorption of such kinetic energy by a piston or other device lowers the temperature and reduces the total heat.

151. Q.—What will be the best thing to put on top of exhaust pipe that will cause enough back pressure to make steam go through 1,000 feet of 3-inch tubes without affecting the engine, which is 150 horse-power? We are going to tap the exhaust pipe about 20 feet below the roof.

A.—Of course, any back pressure in the exhaust pipe will be back pressure upon the engine piston, and a reduction of engine power to that extent. We would put a long bend upon the upper end of the exhaust pipe, turning it to a horizontal position, and have the end beveled to an angle of about 45 de-

grees. Then a valve may be placed over the end of it with a horizontal lever that may be weighted for any pressure required, or the valve may be swung up out of the way to leave the exhaust free, when desired.

152. Q.—We desire to use steam in a shop about 200 feet from the boiler, and we want it at a higher temperature than we can obtain after carrying it so long a distance through pipes. The pipes are well protected, and yet the temperature is too low. Can you advise us of any safe method of superheating this steam by an appliance of gas to the pipes through which it passes?

A.—The protection of the pipes, however effective it might be, would not affect the temperature of the steam delivered so long as the pressure was maintained. If the pressure is not maintained, or nearly so, the pipes may not be large enough for the volume of steam required to be transmitted. Increasing the pressure at the boiler and maintaining that pressure at delivery would increase the temperature of delivery.

153. Q.—Does it cost more to heat by exhaust steam than by live steam?

A.—Frequently it does, but not necessarily. Exhaust steam heating can be put up so as not to increase the back pressure on the engine, then all the heat got from it may be clear gain.

154. Q.—Please give me the temperature of steam at a given pressure; also the amount and size of pipe required to heat an oven for japanning; the temperature of the oven is to be about 300 degrees. Also, give the pressure of steam.

A.—The temperature of steam corresponding to a given pressure you will find in steam tables given in all good engineers' pocket-books. As to the amount and size of pipe, we find by inquiry that the practice is to put in as many feet of 2-inch pipe as can be placed in one row around the sides and top of the oven. For a temperature of 300 degrees you will require a steam pressure of about 75 pounds. Brown & Sharpe Manufacturing Company, Providence, R. I., will, no doubt, furnish you with all the castings, pipes, etc., required for the oven.

155. Q.—What would be the difference in heating value of steam at 5 pounds and steam at 25 pounds pressure in radiators. Would the increased pressure furnish sufficient heat to the radiators to warrant its maintenance?

A.—If the temperature is reduced to that of water at at-

mospheric pressure, the units of heat given off by the steam at 5 pounds pressure will be 970, and that given off by steam at 25 pounds pressure will be 983. The difference is so small that it will not be economical to maintain the pressure at 25 pounds.

156. Q.—I have had an argument with a boiler maker, a man of considerable experience, who says that theory is not practical, and that it cannot be relied upon in practice, and that in bridge work and boiler work drawings and figures cannot be relied upon. My view of the matter is that any supposed theory which does not turn out right is not theory at all; that theory is practical which makes a foot 12 inches in a bridge, boiler, engine or building; if the correct dimensions are written on drawing and the parts of a machine or structure made to these dimensions, these parts will go together perfectly. Now, I have heard many machinists say the same thing as this boiler maker. What is your view of it?

A.—You are perfectly right in your opinion. A boiler maker who insists that drawings are of no use and cannot be relied upon must have had a very limited experience, probably not extending beyond country shops or places where one class of boilers is made from one year's end to the other. We know there are mechanics who do not know the value of a drawing, but these are usually men either without ambition, or who have had no opportunity in finding out the value of a drawing. Before a bridge of any importance is built, the stresses and strains in each member are carefully considered and worked out, then the drawing is made, and after this the bridge is built in exact accordance with the drawing. For building marine engines and boilers drawings are indispensable, and many manufacturers would have to go out of business if they could not rely on their drawings. From a mechanical standpoint we may say that theory is an intelligible conception based upon correct observation of how something has been brought about, and how similar things should be done in the future; such theory must agree with practice. There are theories which simply originated in the mind without any support of observation; theories of this kind are frequently opposed to facts, and when put to a practical test are found to be worse than useless. For instance, the theory adopted by perpetual motion cranks belongs to the latter class of theories.

157. Q.—Does an applicant for appointment as boiler inspector in the United States marine service have to undergo an examination, and, if so, is there any book or pamphlet issued that could be used for self-instruction in the matter? I am a competent mechanic, and have worked at the boiler making business for the past twenty-two years.

A.—You will have to pass an examination. We do not know of any book which contains the questions asked in the examinations, and believe there is none. The questions are such as to test the fitness of the applicant for the position. The applicant must be well informed on matters relating to his business, and be able to answer any questions relating to the same; and besides this, he should have a fair theoretical knowledge of marine engineering. You will undoubtedly be well treated by applying for any other information at the office of the Supervising Inspector, in the Postoffice Building of this city.

Steam Engine.

158. Q.—In what direction does a stationary engine run when it runs forward.

A.—Stand at the cylinder and look towards the flywheel. If the top of the wheel revolves in a direction away from you, then the engine runs forward, or over.

159. Q.—How is the horse-power indicated by a prony brake to be computed?

A.—A familiar arrangement of the prony brake consists of a large pulley on the engine shaft and a clamp surrounding the pulley with large rubbing surfaces. The tension of the clamp should be adjustable; and, as a part of the clamp, an arm should extend out horizontally at right angles to the engine shaft, the end of the arm being supported by the platform of a common weighing scales. The bearing point of the arm should be a knife-edge parallel with the engine shaft. The bearing point of the arm may be at the same hight as the center of the shaft, or it may be higher or lower. The distance of this bearing point from a vertical line passing through the center of the shaft should be carefully measured, and this distance is then the working radius of the brake. The weight of the arm upon the scale when hanging free should be compensated for or should be deducted from all subsequent readings of the scales. The brake being in operation, multiply its working radius by 6.2832, this product by the rotations per minute, and this again by the pressure of the arm upon the scales, and divide the product by 33,000; the result will be the brake horse-power. Thus, say that the length of the arm, measured as described above, is 4 feet, the rotations 150 per minute, and the pressure on the scales 90 pounds; the horse-power will be: $4 \times 6.2832 \times 150 \times 90 \div 33{,}000 = 10.28$ horse-power.

160. Q.—How much increase of power would be obtained from a boiler by raising the steam pressure from, say, 70 pounds to 150 pounds?

A.—The increased economy of high-pressure steam is due to the engine, and not to the boiler, and the increased power obtained from the same boiler by increasing the pressure can only be that due to a smaller consumption of steam per horse-power by the engine. There is no reason why a greater number of heat units should go through the heating surfaces because of an increase of pressure. On the contrary, there should be some loss because of the increased temperature of the water due to increased pressure. In other words, calling a boiler horse-power the equivalent of the evaporation of a definite amount of water from and at 212 degrees, the increase of pressure should lead to a slight loss. If, however, this steam were used in an engine properly designed for it, the reduced consumption of steam per horse-power by the engine would much more than neutralize this loss and give a net gain for the combination of engine and boiler. Boilers do not develop power at all. They simply make steam, and with the steam an engine may develop power.

161. Q.—With an engine of given dimensions—If I add 1 inch to the diameter of the cylinder do I increase the power of the engine the same as I would to add 2 inches to the length of the crank? What is the relative proportion between the increase of travel and increase of cylinder diameter?

A.—With the same mean effective pressure per stroke and the same number of rotations per minute the power will increase directly as the length of the stroke, or directly as the square of the diameter, so that these two particulars can have no constant relation to each other. With an engine with a cylinder 24x24 inches, if the stroke was increased 2 inches the increase of power would be nearly the same as if the diameter of the cylinder was increased 1 inch. The arithmetical statement would be like this: $24 : 26 :: 24^2 : 624$, and then the diameter for the cylinder which, with the original stroke, would give the same power would be $\sqrt{624} = 24.98''$. If, however, the engine cylinder was 24x48 inches, it would only be necessary to increase the cylinder diameter ½ inch to equal an increase of 2 inches in length of stroke. The statement in the latter case would be: $48 : 50 :: 24^2 : 600$, and then $\sqrt{600} = 24.49''$.

162. Q.—Having an engine with cylinder diameter of 7 inches and stroke of 10 inches, at what speed must I run it and what must

be the boiler pressure if driving it at 25 horse-power; also, at what point should it be cut off?

A.—An indefinite number of combinations of speed, pressure and cut-off would give the required power. For each pound of mean effective pressure in the cylinder and for each revolution per minute, the engine will develop .0004 horse-power. Multiply this constant by the proposed pressure and the proposed speed, and you will obtain the horse-power. Thus, if the pressure is to be 50 pounds and the speed 100 revolutions per minute, the power will be .0004 × 50 × 100 = 2. Such an engine would probably have a plain slide valve and the cut-off would not be earlier than at five-eighths stroke.

163. Q.—What is the rule for finding the size of steam engine piston rods?

A.—The investigations of Professor Barr showed that the average practice in this country is represented by the formulas:

$d = .145 \sqrt{DL}$ for high speed and

$d = .11 \sqrt{DL}$ for low speed engines, in which

d = diameter of rod.

D = diameter of piston.

L = length of stroke.

164. Q.—Why is it that iron piston rods are twisted in forging?

A.—The piston rods are twisted to prevent the grain of the iron running in the direction of motion; by so doing grooving is often prevented, and the rod will wear better.

165. Q.—I would like to have a rule or formula for finding the thickness of the walls of a steam engine cylinder, one that will hold good under any pressure and still give thickness enough after the cylinder has been worn and then trued up.

A.—Multiply the diameter of the cylinder in inches by the steam pressure per square inch; also multiply this product by the constant decimal fraction .0001; add to this last product the square root of the diameter of the cylinder in inches multiplied by the constant decimal fraction .15; the result will be the thickness of metal in the barrel of the cylinder. To show the application of this rule we will work out the following example: What must be the thickness of metal in the barrel of a cylinder 49 inches in diameter; steam pressure 60 pounds per square inch? Here we have $(49 \times 60 \times .0001) + .15 \sqrt{49} = 1.34$ inches for

the thickness of the metal. To this should be added, say, ⅛ inch, to allow for wear.

166. Q.—What is the rule for finding the pressure per square inch on the crank pin of a steam engine?

A.—The effective area of a crank pin is taken to be its length multiplied by its diameter. The pressure in pounds is the area of the piston in square inches multiplied by the pressure against the piston. For example, take the instance of a 16-inch cylinder; 80 pounds steam pressure; crank pin 4½ inches diameter and 5 inches long. The effective area of the crank pin is 5″ × 4½″ = 22½″; the area of the cylinder is 201″, and 201 × 80 = 16,080, the total pressure on the crank pin in pounds; then $\frac{16{,}080}{22\frac{1}{2}} = 714$, the pressure in pounds per square inch on the crank pin.

167. Q.—How may I determine how much further the crank of an engine travels in an hour than the piston?

A.—The mean speed of the crank is 1.5708 times greater than that of the piston, hence, if you find how far the piston travels in an hour and multiply this by 1.5708, it will give you the distance traveled by the crank. Suppose the engine with a stroke of 1 foot makes 100 revolutions per minute, to find how far the crank travels in an hour: The piston will travel 2 feet at each stroke, and 2 × 100 × 60 = 12,000 feet per hour, and the crank will travel 12,000 × 1.5708 = 18,849 feet per hour.

168. Q.—Why is a connecting rod made larger at the crank end than at the crosshead end?

A.—Connecting rods are made larger at the crank end for the purpose of overcoming the resistance due to friction, which acts with a greater leverage on the crank pin than on the crosshead pin, the latter pin being smaller in diameter than the former. The stresses due to the inertia of the rod also call for a larger section of the rod at the crank pin end than at the crosshead end.

169. Q.—What is meant by initial pressure?

A.—The pressure at which any cycle or operation begins. In a steam engine it is the pressure in the cylinder at or near the beginning of the stroke of the piston.

170. Q.—Can you give me a rough-and-ready rule for approximating the horse-power of a steam engine? I am associated with a

fellow who has a very quick way of doing it, and I can't quite catch on.

A.—We can give a rule that will certainly be rough enough, and its readiness will depend upon the user, the same as with any other tool. We have to assume that the boiler pressure, the diameter of cylinder and the piston speed are known. Multiply the gage boiler pressure in pounds by the square of the cylinder diameter in inches, and this product by the piston speed in feet per minute. Discard all decimals and cut off three figures from the right, then divide by 84, and the result will be the horse-power. Say that our boiler pressure is 100 pounds, cylinder diameter 20 inches and piston speed 500 feet per minute. Then, $100 \times 20^2 \times 500 = 20{,}000{,}000$. Cutting off the three right-hand figures and dividing as directed, we have $20{,}000 \div 84 = 238$ horse-power. This result gives a mean effective pressure in the cylinder of 50 pounds, or one-half of the boiler pressure. By the regular method of computation with this mean effective pressure, the operation would be like this: $20^2 \times .7854 \times 50 \times 500 \div 33{,}000 = 238$. One-half the boiler pressure is about the mean effective pressure obtained in the cylinder when cutting off at one-quarter stroke with the common boiler pressures of, say, 80 to 100 pounds. The above rule may be made still rougher and readier and, if judiciously used, even handier. Multiply together the boiler pressure, the square of the cylinder diameter and the piston speed, as directed above; cut off four figures from the right-hand, instead of three as before, and divide by 9 for a Corliss or other automatic non-condensing engine, or by 7 for a common slide-valve engine. Say that we have a Corliss engine 18x42 inches, running 60 revolutions per minute with steam at 80 pounds, the operation will be: $80 \times 18^2 \times 420 = 10{,}886{,}400$, and $1{,}088 \div 9 = 121$, nearly. Say that we have a common slide-valve engine, 12x24 inches, running at 120 revolutions per minute with steam at 75 pounds; then $75 \times 12^2 \times 240 = 2{,}592{,}000$, and $259 \div 7 = 37$.

171. Q.—What is a reasonable load per square inch of bearing surface on crank pins and shafts at different speeds? How much of the circumference of the pin or shaft is usually taken for the bearing surface? We have some bearings as follows: Crank shaft, 9 inches diameter, 6 inches long; load on same, 170 pounds pres-

sure, with a 14-inch diameter piston. Now, 14 inches diameter gives 153.9 square inches area, and 153.9 × 170 = 26,163 as the total load at discharge. These proportions seem to be all right for the pressure and speed given above, but when that is exceeded the bearings wear considerably.

A.—In computing the distribution of pressure on crank pins or journals the surface is usually taken as the diameter multiplied by the length, which is a little less than two-thirds of the actual surface subjected to pressure. The pressure should not exceed 500 pounds per square inch of surface thus computed. In this case we have 9 × 6 = 54 square inches, and 26,163 ÷ 54 = 484 pounds pressure per square inch, so that it is within the limit, while the number of revolutions is only about one-half what is common in marine practice, where the above rule is used. It is the common experience that short bearings are more apt to heat than longer ones, if no other conditions come in to modify the result, and in this case the bearing seems to be very short. We infer that the above pressure of 170 pounds per square inch at discharge applies to a compressing cylinder, and if so, then the full pressure would only occur at the end of the stroke. If the cylinder is vertical, of course the weight of the shaft and what it carries, and of the reciprocating parts, should be added to the total pressure. Probably more attention should be given to the lubrication; not merely to the quantity or quality of the oil applied, but also to the place at which it is applied.

172. Q.—How may the evil effects of excessive clearance be lessened?

A.—What are the evil effects, and where is the line drawn between clearance and excessive clearance? In some sense, is not all clearance excessive?

173. Q.—When the valves of an engine are set how can I tell which way it will run?

A.—Put the engine on either dead center; then you will find the steam valve just beginning to open the port. Then look at the eccentric and connections, and if you have any idea of mechanical appliances you can tell which way the crank must turn to continue to open the steam port. That is the way the engine will run. If you cannot tell without, then turn the engine in one direction or the other and you can observe.

174. Q.—In what condition should a steam engine be when the main valves are adjusted?

A.—All other connections and parts should be properly adjusted, and for the final adjustment of the valves the parts of the engine should be at normal running temperature, or the engine should have been thoroughly warmed up by the steam.

175. Q.—When lap is added to an ordinary slide valve is it necessary to change the eccentric to give the valve more travel, and if so, why?

A.—The addition of lap will generally prevent the valve from opening sufficiently for the proper admission of steam; hence it is usually necessary to increase the travel when the lap is increased in order to provide the proper port opening. An increased travel of valve also opens the port more rapidly, which is an important consideration.

176. Q.—By what rule can the average pressure upon the piston of a steam engine be found? For instance, suppose the pressure to be 60 pounds per square inch, and cut-off at half stroke, what will be the average pressure, and by what rule can it be found?

A.—This question is continually coming up, like the computations for screw cutting on the engine lathe. In the first place, the computation, as with nearly all computations relating to steam, must be based upon the absolute pressure of the steam, or the gage pressure with that of the atmosphere added. The gage pressure in this case being 60, and the atmospheric pressure being 14.7, the absolute pressure will be $60 + 14.7 = 74.7$. As the steam is cut off at half stroke, the ratio of expansion is 2; and we find in a table of hyperbolic logarithms, in some "Engineer's Pocketbook" or book of tables, the hyperbolic logarithm of 2, adding 1 to it; or in some tables, as in Hemenway's book on the "Indicator," the 1 is added to the logarithm in the table. The hyperbolic logarithm for 2 we find to be .693; or, adding 1 to it, we have 1.693, and this we multiply by the absolute steam pressure, which is 74.7, then $1.693 \times 74.7 = 126.4671$. We divide this by the ratio of expansion, $126.46 \div 2 = 63.23$. Then we subtract the atmospheric pressure from this, $63.23 - 14.7 = 48.53$, and this is the mean or average pressure. This is the theoretical pressure, as generally computed; but the actual mean effective pressure will be somewhat different from this, as several things will affect it, such as the cylinder clearance, condensation in the cylinder, sharpness of cut-off, exhaust opening, capacity of exhaust pipe, etc.

177. Q.—Do not automatic cut-off valves, which control speed, by changing their travel, throttle the steam at ports when engine is lightly loaded? If so, does not this reduce the efficiency of engine?

A.—The efficiency is no doubt reduced by this means, but every style of engine, of course, has its point of best efficiency, and in none of them is it found when the engine is doing the least work.

178. Q.—In setting an Allen valve is it the same as a slide valve, or does it require less lead?

A.—As the Allen valve has two openings instead of one, the lead should be a little less than for the plain slide valve.

179. Q.—Will a stationary engine pull the same load as well when running under as when running over?

A.—Yes; a stationary engine is usually able to work as well in one direction as the other. They are usually run over, but George Corliss preferred to run under, on account of the effect in relieving the guides of the weight of the crosshead and connecting rod.

180. Q.—What is a direct-acting engine, and what is not?

A.—Nearly all the common engines seen are direct-acting. A beam engine is not a direct-acting engine.

181. Q.—Will engines govern as closely under variations of steam pressure as under variations in load?

A.—Some may, but generally they will not, because the variation in steam pressure generally varies the work that the governor has to do in controlling the speed.

182. Q.—Is there any automatic engine made that will govern as closely as within 2 per cent.? Say, running with 80 pounds steam cut-off at one-quarter stroke, if the steam pressure is reduced to 60 pounds, will the engine run at the same speed?

A.—The load remaining the same, the speed will not be the same, but there are builders of automatic engines that will guarantee less variation than 2 per cent. under the conditions named.

183. Q.—Why does our engine back-lash in passing the centers? It is 20x48 inches, running 52 revolutions, and has a flywheel 15 feet diameter, weighing about 4,800 pounds. The valve has 1 inch outside and 7-16 inside lap; travel, 4½ inches. The boiler pressure is 80 pounds.

A.—The trouble is in having too light a flywheel. If the wheel is 15 feet diameter, the *rim* should weigh about 8 tons.

184. Q.—In speaking of the horse-power of an engine, is there any sense in saying that an engine of 25 horse-power is geared up to 50 horse-power?

A.—There is no sense in it. An engine that can steadily develop 50 horse-power is a 50 horse-power engine, and if such an engine is developing 25 horse-power only, it is not doing its full duty, and it cannot be justly said that it is a 25 horse-power engine.

185. Q.—The engine in question is used for hauling logs; it is a portable engine with two cylinders 7x12 inches, with a vertical boiler carrying a pressure of 130 pounds. On the crank-shaft is a pinion driving a drum which makes one turn for every nine revolutions of the crank. How many horse-power does this engine develop running at the rate of 75 revolutions per minute, cutting off steam at three-quarters stroke? I had a dispute with the man who runs it.

A.—We hould rate it at 40 horse-power.

186. Q.—What is the proper way to determine the lengths of links for engines?

A.—In determining the length of Stephenson's link, the first thing to do is to find the distance between the centers of the eccentric rod pins. The usual practice is to make this distance equal to 2¼ to 2½ times the throw of the eccentric, and occasionally, when space permits, to 3 times the throw. By "throw" is meant twice the eccentricity. The distance should not be much less than here given, because decreasing it will increase the slip of the block in the link; on the other hand, the design of the engine and the conditions under which it has to work usually put a limit to this distance. For the length of the link add to the distance as found above the length of the link block, and sufficient clearance for the slip of the block; the sum will be the length of the link. This refers to the ordinary open or slot links, the length of the link being the length of the slot.

187. Q.—I have a plain slide-valve engine, cylinder 12 inches diameter, 24 inches stroke, running at the rate of 130 revolutions per minute, to drive a brick machine at the same speed. Would it save fuel to reduce the speed of the engine and put on a larger driving pulley? If so, what would be the proper speed of the engine? It needs only 20 horse-power to run the brick machine at 130 revolutions per minute.

A.—The engine is much too large for the work it has to do. If in good condition it should develop three times as much power, and if it can develop only 20 horse-power, there is something decidedly wrong about it, and it must waste a great amount of fuel. In reducing speed the engine will not even then be an economical one. The best plan is to get a smaller engine for the work to be performed. The saving of fuel will soon pay for the expense incurred.

188. Q.—I have a single-acting engine, with cylinder 5 inches diameter, stroke 8 inches, piston making, say, 500 strokes or more a minute, and steam pressure varying from 50 to 250 pounds per square inch. Now, if the valve cuts off steam at one-eighth of the stroke, will the steam lose its pressure and heat sufficiently so that a condenser can handle it? Or how many units of heat at most will a condenser handle?

A.—A condenser can always be designed to condense nearly all the steam that is put into it. There is no difficulty in making a condenser suitable for the work you mention, providing the locality affords plenty of cold water required for condensation.

189. Q.—Will a steam engine cylinder surrounded by exhaust steam be more economical than if left exposed to the atmosphere at an ordinary temperature?

A.—No; either way is bad practice. The cylinder should always be well lagged.

190. Q.—Does the lead in small marine engines or tug-boat engines increase or decrease as the link is hooked up? Why, in a hoisting engine with a link motion, is the lead made to decrease as the link is being hooked up, while in locomotives it is made to increase?

A.—It generally increases. In hoisting engines, a decrease of lead in hooking up the link is a matter of convenience. This enables the engineer to stop the engine without closing the throttle valve. In locomotives the link is used for changing the point of cut-off so as to work the steam expansively, and since in these engines the minimum amount of lead is at full stroke, a decrease of lead when the engine is cutting off earlier is not admissible, as this would tend to stop the engine. Of course, when a stationary link is used, the lead is constant for all cut-offs; but in shifting links the lead can be made to increase or

decrease by connecting to it the eccentric rods in a suitable manner.

191. Q.—Please give me a rule for finding the point of cut-off in a steam cylinder, the initial and terminal pressures being given. For instance, the initial pressure is 100 pounds and the terminal pressure is 8 pounds, at what point of the stroke should the cut-off occur?

A.—We assume that the above pressures are those indicated by the gage. If so, add 14.7 pounds to each, which will give the absolute pressures. Divide the absolute initial pressure by the absolute terminal pressure; use this quotient for the denominator of a fraction whose numerator is 1; this will be the fractional part of the stroke at which steam should be cut off. In the example given, we have $\frac{114.7}{22.7} = 5$, hence the steam should be cut off at one-fifth of the stroke. The above result will be somewhat affected by the clearance, which we have neglected.

192. Q.—Can a Corliss engine be run with the steam and exhaust valve disconnected at one end of the cylinder, the exhaust valve being removed entirely, and the admission valve blocked? My object is to run the engine during the time a new stem is being fitted into the exhaust valve.

A.—Yes, provided the flywheel is heavy enough to carry the engine over the dead centers and through one-half of the stroke. You may also have to close the exhaust port after the valve has been taken out. Of course, the power developed by the engine running with one steam and one exhaust valve only will be much reduced.

193. Q.—Which travels faster, the crank pin or the piston of an engine, and why?

A.—Take your dividers and describe a circle, which call the path of the crank pin. The diameter of the circle will then represent the stroke of the piston. A little consideration will show you that while the crank pin is traveling entirely around this circle the piston will travel a distance equal to twice the diameter. As the circumference of a circle is equal to 3.1416 times its diameter, you will readily see that the mean speed of the crank pin must be greater than that of the piston.

194. Q.—For what other reasons besides being out of line or keyed too tightly do crank pins heat?

A.—They will heat if not large enough for the work; if good lubrication is not provided; if dirt gets inside the brasses; if the brasses are not properly fitted; or if the brasses or pin are not of good material and smooth. Sometimes when an engine is working the springing of parts will throw them out of line.

195. Q.—In reading works and articles on the steam engine I frequently find a statement to the effect that it is not economical to expand steam below the pressure that will overcome the friction of the engine; also, the loss that comes from making a pump of the engine. Can you explain?

A.—Such statements, standing by themselves, are misleading and, if true—particularly the first one—are so by accident only. It would be bad practice, generally, to design a non-condensing engine, which, we understand, you refer to, so that steam would, with the regular load, be expanded lower than about 5 pounds above atmosphere. But this is something, so far as the economical use of steam is concerned, with which the friction of the engine has nothing to do. It might quite as well be said that expansion should not be lower than the pressure required to drive the "big planer," or something of the sort. But it is one thing to design an engine for a definite load, and another thing to operate it under existing conditions as to load, steam pressure available, speed, etc. Suppose it took 20 pounds pressure to overcome the friction of the engine. It would not be good steam economy to stop expansion at 20 pounds above atmosphere, which you would do if you took the first statement literally. The conditions in operating a steam engine are frequently such that it is economical to carry expansion to, or even below, the atmosphere. When expansion in a non-condensing engine is below the atmosphere it is likened by some to a pump, we suppose, because when the exhaust valve is opened the flow will, at first, be into instead of out of the cylinder. If this inflow was of air of ordinary temperature, it would tend to cool the cylinder. But the inflow is generally through a pipe of considerable length, the contents of which are nearly as warm as—perhaps warmer than—the contents of the cylinder, so that under conditions ordinarily obtaining no particular harm results.

196. Q.—How is the point of compression of a steam engine influenced by the speed?

A.—The object of compression is two-fold; first to fill the clearance spaces with steam, and second to absorb the momentum of the reciprocating parts, and so pass the centers without pounding. The point of compression is made earlier in the stroke in the case of high-speed engines, partly because the clearance spaces are relatively larger, so that more compression is needed to fill them, and partly because, owing to the higher speed, more cushion is needed to absorb the momentum. It should also be said that, with the forms of valve gear used on high-speed engines, a heavy compression is a necessity, and could not be avoided even if it was desired.

197. Q.—Is there any rule followed in steam engine building for determining the length of the connecting rod with reference to the stroke? Which are the ratios commonly met with in practice? And is there a certain ratio predominant?

A.—The length of the connecting rod depends much on the design and duty of the engine. For large stationary engines the length of the connecting rod is 2⅔ to 3 times the stroke of the piston when it is practical to afford the space; on smaller engines the ratio is sometimes reduced. In marine engine practice the length should be, if possible, not less than twice the stroke. Those of the horizontal direct-acting engines on warships can seldom be as long as this; they are generally 1¾ times the stroke. Those of return connecting rod engines are never less than twice the stroke, and sometimes as much as 2½ times; those on trunk engines 2 to 3 times the stroke.

198. Q.—Why does throttled steam become superheated?

A.—In referring to steam tables you will find that the heat in a pound of saturated steam of any given pressure is greater than the heat in a pound of saturated steam of lower pressure. But a pound of steam throttled down to a lower pressure will contain nearly the same heat as a pound of saturated steam of the higher pressure; consequently it will have more heat than is necessary for keeping the steam in a vaporous state, and this excess of heat will superheat the throttled steam to a slight extent.

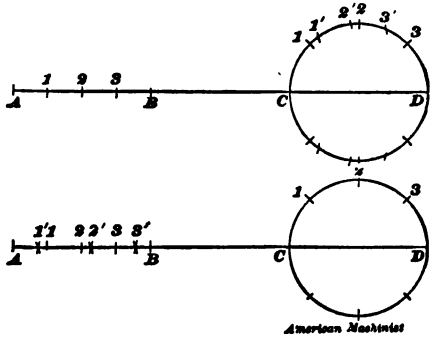
199. Q.—How many actual pounds can a 1 horse-power steam engine raise when the connecting rod is connected direct to a winding drum instead of a crank disk? The diameter of the winding drum is equal to the stroke of the piston.

A.—The number of pounds that this engine can raise will depend on the speed at which it is run. However, to make this plain, we shall assume that the stroke of piston is 6 inches; hence the diameter of the winding drum will also be 6 inches; the circumference of this drum is 18.85 inches, or 1.57 feet, and if the thickness of the rope is neglected, then the weight or load will be lifted 1.57 feet during one revolution. If now the engine runs at the rate of 200 revolutions per minute, then the load will be lifted through a distance of $1.57 \times 200 = 314$ feet during one minute. One horse-power is equal to 33,000 pounds lifted 1 foot high per minute; hence the number of pounds which the engine can lift will be $\frac{33{,}000}{314} = 105$. In this computation friction has been neglected. From this it will be seen that if the speed of engine is increased without changing the power the number of pounds which the engine can lift will be less than found above, and if the speed of engine be decreased without changing the power the number of pounds lifted will be greater than 105. Attaching the connecting rod to the drum or to a crank disk will not make any difference in the load, so long as the speed of engine or diameter of the drum is not changed.

200. Q.—Please give me some information as to the effect of the angularity of a connecting rod on the travel of the piston, and if the same effect is not produced also on the valve travel, and state cause for same.

A.—As to the cause, we can dismiss that at once by simply saying that it is so, just as two and two are four, and nobody knows the cause. The figure opposite illustrates the effect of the angular action of the connecting rod upon the piston stroke. *A B* represents the travel of the center of the crosshead pin, and the circular line represents the travel of the center of the crank pin. The points 1, 2 and 3 represent respectively one-quarter, one-half and three-quarters of the travel of the crosshead pin and a quarter, a half and three-quarters of the corresponding half-revolution of the crank. The length of the connecting rod is *A C* or *B D*, in this case equal to twice the travel of the piston. If now, referring to the upper diagram, we take the length *A C* and measure from the points 1, 2 and 3 on the line of travel of the crank pin, we find that the other end of the rod will not

come at the points 1, 2 and 3, as it should do to have equal measurements of the crank for equal portions of the piston travel, but will come to the points marked 1′, 2′ and 3′, and this effect is due to the angular action of the rod. In the lower diagram we take the same length of connecting rod and measure from points 1, 2 and 3 of the crank path to the line of the crosshead travel, and we find the points 1, 2 and 3, none of which coincide with the quarters of the stroke. With a proportionately longer connecting rod the effect of the angularity upon the travel is less. As the length of the eccentric rod is usually much greater than that of the connecting rod, while the travel of the valve is much less, the effect of the angularity of its own rod is not much felt by

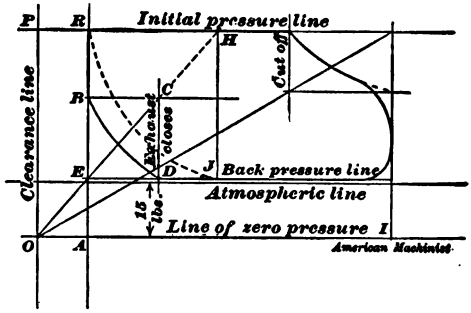


the valve, but it is constantly in a false position on account of the angularity of the main rod.

21. Q.—We are troubled by the pounding and unsatisfactory working of a 9x14-inch slide-valve engine that carries 120 pounds of steam and makes 150 revolutions. Can you point out the cause of the trouble? The enclosed sketch gives dimensions of valve and ports.

A.—According to sketch, the exhaust edges are line and line, and it is more than probable that the trouble is due to want of cushion. At the given speed there should hardly be less than three-fourths cushioning; that is, the point B in accompanying diagram should be $E\ B = \frac{3}{4}\ E\ R$. This supposes a clearance volume of about 7 per cent.—a usual value for such engines. Compute the clearance volume—from piston face to valve seat—

and divide the amount in cubic inches by the cross area of cylinder; the quotient will be the relative length cylinder due to clearance volume. Draw a line *O I* (as per figure) and make *O A* equal to the above found clearance length, and take *A I* equal to the length of stroke of piston. Set up *O P* equal to initial pressure in cylinder, and take also *A E* equal to, say 16 pounds (which allows one pound above atmosphere for increase of back pressure). From *O*—which is the "origin" or zero point of both pressure and volume—draw a diagonal, as shown, and intersect it at *C* by a horizontal from the point *B*, to which the cushion is to rise. A vertical from *C* will cut the back pressure line at the proper point *D*, at which the exhaust must close, and having this latter point, the inside lap of valve can be readily

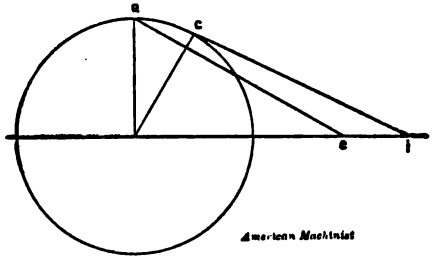


found, either from a drawing of the valve gear or by placing the engine piston in the proper position and adjusting lap and eccentric to suit. The continuation of *O E* to *H* gives *J* as the point of closing exhaust to bring cushion full up to *R*, but unless there is very little clearance (say 5 per cent.), this causes too great back pressure near ends of stroke for single cylinder engines. Your valve will probably require ⅛ to 3-16 inch inside lap, but not having the drawing of valve gear this must be left for your own determination.

202. Q.—What is the relation of the maximum speed of a piston to the mean speed as usually stated? Is the relation constant, so that the same multiplier may be used for all ordinary cases?

A.—Piston speed is usually stated as the product of double the length of the stroke by the number of crank revolutions per

minute. Thus, at 50 revolutions per minute and 4 feet stroke the piston speed would be said to be $4 \times 2 \times 50 = 400$ feet per minute. Now, the piston travels a distance equal to twice the diameter of the circle described by the center of the crank pin, while the pin itself, of course, travels the circumference of the circle. With a connecting rod of any length, or with a slotted crosshead or Scotch yoke, when the crank is at right angles to the line of piston movement the piston must travel at the same speed as the crank pin. The piston speed, then, in the case above cited would really be $4 \times 3.1416 \times 50 = 628.32$ feet per minute. Multiplying, therefore, the stroke and number of revolutions per minute by π, or 3.1416, will give the maximum piston speed with sufficient accuracy for any practical purpose. There is a little portion of the crank revolution where the piston actually travels faster than the crank pin, as anyone may readily con-



vince himself by making the construction shown in the sketch, where the line *e i* is longer than *a c*. The short connecting rod, of course, exaggerates the effect.

203. Q.—How can I silence the exhaust of a 3x4-inch high-pressure engine?

A.—You can probably do this by a suitable arrangement of some one of the exhaust heads sold by dealers. It can be done by discharging the exhaust into a box of pebbles.

204. Q.—Suppose a cylinder is bored to 24 inches diameter, what must be the diameter of the piston?

A.—This depends to some extent on the kind of packing used. But generally the piston head is turned 1-32 inch less than the diameter of the cylinder. Sometimes less or more than 1-32 inch is allowed, so as to suit individual experience or prejudice.

205. Q.—What is a simple rule for computing the size of steam chest of a small engine, say, a hoisting engine with cylinders 6x10 inches?

A.—The only rule for determining the size of steam chest is to make it large enough, and no more, for the valve and its travel, and allow a passage sufficiently large for the steam to surround it.

206. Q.—What is the difference between a surface condenser and a jet condenser?

A.—The surface condenser consists of a large cast-iron vessel containing a coil of brass pipe. The cooling water circulates within the pipes, and the exhaust steam is admitted to the vessel around the pipes, the steam being condensed by the cold surfaces. In a jet condenser the water is injected, through a rose head, directly into the interior of the condenser. It will be seen that in the surface condenser the cooling water and condensed steam are kept separate, so that salt or otherwise impure water may be used without contaminating the condensed water which is fed back into the boiler. With the jet condenser impure condensing water contaminates the condensed steam, compelling the use of the impure water for the boiler. Consequently, the jet condenser is commonly used when the condensing water is pure, and the surface condenser when it is impure.

207. Q.—At an altitude of 5,200 feet above the sea level is the vacuum in a condensing engine as effective as at the sea level?

A.—Yes.

208. Q.—How many inches should the vacuum gage show when the engine is in good working order at the above altitude?

A.—About 20 inches.

209. Q.—Is a given steam pressure as shown by the steam gage as effective at the altitude as at the sea level?

A.—The absolute steam pressure at any place is equal to the pressure shown by the steam gage plus the atmospheric pressure. Since the atmospheric pressure decreases with an increase of altitude, the absolute pressure for any recorded gage pressure will be greatest at the sea level, and consequently the same steam pressure as indicated by the steam gage will be more effective at sea level than at the given altitude.

210. Q.—Why should a compound engine have a cut-off valve on the low-pressure cylinder?

A.—The cut-off valve on the low-pressure cylinder is generally used for adjusting and equalizing the work performed by the steam in the high and in the low-pressure cylinders.

211. Q.—Where should the point of cut-off be?

A.—The point of cut-off of the high-pressure cylinder depends upon the economy desired. For best economy the cut-off of the low-pressure cylinder should be set at such a point that the volume of this cylinder at cut-off shall equal the volume of the high-pressure cylinder at release. This does not, however, give the quickness of action to the governor that is desirable for many purposes, and many engines have the cut-off of the low-pressure cylinders connected to the governor to increase the quickness of the governor's action. This is, however, undoubtedly a defect, so far as the strictly correct use of the steam is concerned.

212. Q.—How should the slide valves of compound marine engines be set?

A.—The slide valves are set substantially like those of simple engines, except that the low-pressure valve should give a greater lead to the exhaust.

213. Q.—L asks for a method of preventing condensing engines from racing when the load is thrown off.

A.—At the power house of the Lenox avenue line of the Metropolitan Traction Company of this city we recently saw a provision for this difficulty, which consisted of a special stop valve held open by a catch. A special governor, arranged to lift at a speed slightly above normal, controlled this catch. On the speed rising to a point to raise the governor, the catch is released and the valve closes itself. A method followed by Hewes & Phillips is to set the steam valves with no lead, or with negative lead, and then adjust the cut-off cams so they will trip the valves before the engines take steam.

214. Q.—What is meant by running with vacuum alone? Is it with the exhaust pipe coupled to condenser, with no steam connection?

A.—No. What is usually meant is that steam is supplied to the cylinder at or below atmospheric pressure. It is, of course, not correct to say that vacuum runs the engine in such a case, because a vacuum cannot do work. It is the pressure of steam which does the work; but if this pressure is at or below at-

mospheric pressure, then the pressure in the so-called vacuum or in the hot well must be still lower in order that there may be an unbalanced pressure in the cylinder to move the piston. If the exhaust pipe were connected to a vacuum and there was no steam connection, then the atmosphere, if admitted to the cylinder, would drive the engine equally as well as steam at the same pressure, so long as the vacuum could be maintained; but as the air, when it passed through the cylinder to the condenser, could not be condensed, but would have to be removed by pumping it out against the resistance of the atmosphere, nothing would be gained.

215. Q.—In a triple-expansion engine, with a constant load and constant steam pressure, will not the work done by the low-pressure cylinder be increased by giving it a later cut-off?

A.—The contrary is true. The work of the low-pressure cylinder will be increased by giving it an earlier cut-off. The change of the cut-off will have a twofold effect. The earlier cut-off will increase the receiver pressure and also the back pressure in the intermediate cylinder, so that the work done by the intermediate cylinder will be diminished, but the work of the low-pressure cylinder will be increased to about the same extent, the increase of pressure more than compensating for the reduction of volume. As the same weight of steam passes through the low-pressure cylinder in either case, it is not difficult to see that the higher initial pressure will do more work.

216. Q.—What should be the temperature of the water in the hot well with the injection water at 60 degrees, and how do you get at it by calculation?

A.—Not only the temperature of the injection water, but also the quantity is to be taken into account. It is usual to allow for the injection water about 27 to 30 times the weight of the steam, and then the temperature of the hot well should not be above 120 degrees.

217. Q.—I am called upon to repair a steamboat engine; the trouble is that of poor vacuum; there is no leak about the connections; the circulating pump and all passages are large enough. The outlet for the water of condensation is about 6 feet lower than the air-pump inlet. I think the trouble is there, due to the head of the water, and the vacuum is poor in proportion to that head

of water remaining between the condenser and the air pump. Please give your advice.

A.—The unsatisfactory vacuum is due to the head of water remaining between the condenser and the air pump; this will be evident from the fact that the pressure which supports this head of water must be the pressure in the condenser, and this, of course, will reduce the vacuum. The condenser and air pump should be brought near to a level; or, better still, the air-pump inlet should be a little below the outlet of the condenser.

218. Q.—What is the method for calculating the pressure in the receiver of a compound engine?

A.—This pressure depends upon the ratio between the volumes of high and low-pressure cylinders measured at point of cut-off. The former measures the volume of steam taken from the boiler, and the latter the volume taken from the receiver, and, the weight of steam being the same in both cases, the pressures will be inversely proportioned to these volumes—expansion of the steam being supposed to be in accordance with Mariott's law, as it actually is nearly enough for such calculations. That is

$$\left.\begin{matrix}\text{Pressure}\\ \text{in}\\ \text{receiver}\end{matrix}\right\} = \left\{\begin{matrix}\text{Pressure at}\\ \text{cut-off in}\\ \text{H. P. cyl.}\end{matrix}\right\} \times \frac{\text{Vol. of H. P. cyl. at cut-off}}{\text{Vol. of L. P. cyl. at cut-off}}$$

The presence or absence of "drop" in the receiver pressure is determined by the point of cut-off in the low-pressure cylinder. If the volume of the low-pressure cylinder at cut-off exceeds that of the high-pressure cylinder at release, this drop will be present, because a greater volume of steam is taken out of the cylinder by the low-pressure cylinder than is put into it by the high. If, however, the low-pressure cut-off be shortened the receiver pressure will rise until, when the volume of the low-pressure cylinder at cut-off equals that of the high-pressure cylinder at release, the volume taken out will obviously equal that put in, and there will be no drop. The above ignores the question of condensation, which will modify the result somewhat, but the results obtained as above will be substantially correct.

219. Q.—In a triple-expansion engine, what is considered a fair allowance of water consumption per indicated horse-power?

A.—Fourteen to twenty pounds, according to conditions; in some cases less.

220. Q.—What is gained by the use of a cut-off on the low-pressure cylinder of a compound engine?

A.—The cut-off on the low-pressure cylinder brings about better economy in the use of steam. Some of the reasons for this are that it provides less variation in the temperature of the high-pressure cylinder and less fall of pressure between the cylinders.

221. Q.—Suppose a cut-off is for the purpose of saving steam. Where is this steam that is cut off in the low-pressure stored until the next stroke, and why does it not result in excessive pressure against the high-pressure piston?

A.—In compound engines, where steam is cut off the low-pressure cylinder, there is a receiver between the two cylinders, not necessarily a separate vessel, but may be made up of the space in the pipe and steam chest of the low-pressure cylinder, and the steam from the high-pressure cylinder exhausts into this receiver, or space, without very materially increasing the pressure after cut off in low pressure cylinder. The pressure between the cylinders is higher for the cut-off on low-pressure cylinder, but this amounts to doing more work in the low-pressure and less in the high-pressure cylinder.

222. Q.—If in the cylinder of a non-condensing engine the pressure is 50 pounds per square inch, what will it be with a condenser, and why?

A.—It will be 50 pounds, as before. The condenser does not add anything to the pressure; it simply removes more or less perfectly the back pressure due to the atmosphere. This back pressure is ordinarily about 14.7 pounds per square inch, from 6 pounds and upwards of which may be removed by the use of the condenser.

223. Q.—What saving in fuel is effected by the compound engine?

A.—Manufacturers of steam engines will generally guarantee from 10 to 30 per cent.

224. Q.—How does a compound locomotive carry the water necessary for condensing the steam?

A.—Compounding does not necessarily imply that the engine is worked condensing. In a compound locomotive the steam is

not condensed; expansion is begun in one cylinder and completed in another; but the steam is then exhausted into the atmosphere instead of into a condenser.

225. Q.—Will an engine 16x24 inches, running 82 revolutions, belted direct to line shaft, cutting off at one-eighth stroke, use more steam than one 9x12 inches, cutting off at three-eighths stroke, speed 270 revolutions?

A.—The small engine cutting off at three-eighths stroke would, supposing both engines to be properly proportioned, and running non-condensing, do materially more work than the large one at the slower speed. Assuming the small engine to do the same work as the large one does when cutting off at one-eighth stroke, with, say, 80 pounds steam pressure, then the small one should use the least steam, because the large one is greatly underloaded, and an underloaded engine is the reverse of economical in its operation.

226. Q.—Do compound engines having crank pins at right angles or opposite give the best results.

A.—So far as steam economy goes, there is no difference due to the location of the crank pin, provided the engine is of the receiver type. Engines having the crank pins at right angles are necessarily of the receiver type, while those in which the movement of the pistons is simultaneous are not necessarily so, and formerly they were not provided with receivers. The turning moment is more uniform with the cranks at right angles, and this arrangemnt is, on this account, preferred.

227. Q.—Give a rule for balancing a slide valve by means of rectangular strips bearing against a surface above the valve, such as are frequently used in locomotives. The steam ports are 1¼x16 inches; exhaust port, 2½x16 inches; bridges, 1 inch wide; outside lap, ¾ inch; inside lap, none; steam pressure, 180 pounds per square inch.

A.—The area on top of valve which is not exposed to the steam pressure, measured from outside to outside of strips, should be two-thirds of the area of the face of the valve. The strips should be 1¾ or 2 inches deep; the latter dimension is the better one if it does not contract the exhaust cavity in the valve too much, and ½ inch is about the proper thickness of the strips. The strips are held up by spiral springs; these springs

are made of steel, sometimes of hard brass, the diameter of wire ranging from 1-16 to ⅛ inch. Sometimes the strips are held up by elliptic springs, one being placed under each strip. If helical springs are to be used, two for each short strip and five for each long strip will be sufficient for this size of valve. When new, the strips should not project more than 1-16 inch above top of valve.

228. Q.—How can I set the Meyer valve gear?

A.—In the first place, set the main valve correctly in the same manner as an ordinary slide valve is set. We shall assume that this has been done, and confine our attention to the cut-off valves. Set the cut-off eccentric directly opposite the crank; place the cut-off valves in the center of their respective threads, as near as can be done by ordinary measurements (great accuracy is not necessary) and make complete connections between eccentric and cut-off valves; also, connecting between main valve and eccentric. Now set the crank in position at which, under ordinary conditions, the steam is to be cut off; then set the corresponding cut-off valve to cut off at this point; this is accomplished by turning the valve stem so as to spread the valves or draw them together, as the case may require. Now turn the crank in the direction in which the engine is to run until the piston is at the same part of the stroke as at the other end of the cylinder when the cut-off took place. If now the corresponding valve is not in a position to cut off, then lengthen or shorten the distance between the valves and eccentric by one-half the difference that this valve is out of its correct position. Lastly, turn the valve stem so as to set the valves for the correct points of cut-off. Verify the result by turning the shaft through two or three revolutions; a little readjustment may be necessary. The above method of setting is for valves whose outer edges close the ports. When the inner edges close the ports the cut-off eccentric must be set in direct line with the crank. These positions of the cut-off eccentrics are correct for marine, hoisting and other engines which are to turn in both directions, since the motion of the cut-off valves is then correct for both forward and backward rotations. In stationary engines the angular location of the cut-off eccentrics is not a matter requiring great exactness. In these engines the cut-off eccentric is not usually placed so far in ad-

vance of the main eccentric; a common location is 45 degrees in advance, the position depending much on individual judgment and preference.

229. Q.—What are inverted cylinders, as the term is applied to marine engines?

A.—Inverted cylinders are cylinders which are placed above the crosshead, and which have the piston rod and stuffing box below them. Nearly all marine engines now used for turning screw propellers have inverted cylinders.

230. Q.—We have a stern-wheel boat with two high-pressure engines, one on each side; the cylinders are 8 inches diameter and 36 inches stroke. We would like to know if it would be feasible to take one of the high-pressure cylinders out and replace it with a low-pressure one. The engines are 17 feet apart. What diameter should the low-pressure cylinder be? We use a steam pressure of 100 pounds per square inch.

A.—It is quite practical to change the two single-expansion engines into a compound engine by taking out one of the cylinders and replacing it by one 14½ inches diameter.

231. Q.—What is the difference between stopping an engine on its center or stopping it off the center?

A.—If the engine has an unhooking gear it does not make any difference where the engine is stopped, so that it is not on the dead center. If the engine has not an unhooking gear it is best to stop it directly after it has passed the dead center, so as to leave the greater part of the stroke through which the piston must travel in starting the engine, by which a sufficient momentum will be obtained to help the engine over the following dead center.

232. Q.—Please give a rule for figuring the area of the air pump and condenser for a steeple compound condensing engine.

A.—The air pump usually has one-sixteenth the capacity of the low-pressure cylinder. Multiply the area of the piston in square inches by the stroke in inches and by the number of strokes per minute, and divide the product by 16 multiplied by the number of strokes of pump per minute, and the result will be the required capacity of the pump in cubic inches. The same thing is stated by formula like this:

$$\frac{A \times S \times N}{16 \times N_p} = C$$

If the pump is a part of the engine, and makes the same number of strokes with it, that factor may, of course, be omitted. If the pump is single acting, and is one-half the diameter and one-half the stroke, that will give it the required capacity. For a surface condenser allow 2 square feet of cooling surface for each indicated horse-power.

233. Q.—An indicator diagram from a non-condensing engine shows an initial pressure of 70 pounds, gage; the steam is compressed in the clearance space to 35 pounds, gage; what proportion of the steam required to fill the clearance to the initial pressure of 70 pounds is furnished by the compression?

A.—Referring to Kent, we find that the weight of 1 cubic foot of saturated steam at 70.3 pounds gage is .1971 pound, while the weight for the same volume at 35.3 pounds is .1198. Then .1198 ÷ .1971 = .6078, or, say, compression supplies .6 of the steam required to fill the clearance.

234. Q.—Should the bucket valve of the air pump break, what effect would it have on the engines?

A.—The immediate effect would be an increase of back pressure, which increase would continue until the pressure became somewhat above that of the atmosphere, when the exhaust would blow up through the air pump.

235. Q.—What is the proportion of cooling surface in surface condensers to the size of the engine?

A.—The following table gives modern marine practice:

Absolute Terminal pressure	Square feet of surface per I H P.
30 pounds	3.00
20 "	2.50
15 "	2.25
12½ "	2.00
10 "	1.80
8 "	1.60
6 "	1.50

The table is based on the use of sea water of an average temperature of 60 degrees. Another rule, based on a temperature of 75 degrees in the circulating water and a vacuum of 25 inches, is $S = \frac{17\ W}{180}$ in which

S = condensing surface in square feet.

W = pounds of steam to be condensed per hour.

236. Q.—I want to make a lazy tongs which is to be used on a 24x48-inch engine; please give me dimensions, distance of stake from crosshead, and other particulars.

A.—A lazy tongs or pantagraph is usually made of cherry wood; the long levers are 1⅛ inches wide and 5-16 inch thick; the distance between centers of pivots is 16 inches. Every alternate lever is made of two strips of the above dimensions, and the others are made of single strips, passing between the strips of the double ones. The pivot holes should be bushed, and the pivots nicely fitted. The end pivots should have a projection below of, say, 2 inches, with the end somewhat pointed. The engine crosshead must have a vertical hole in it somewhere to receive the projection of one of the pivots. A stake is set in the floor near the guides, having a socket in its top to receive the other pivot. The stake socket must be level with the crosshead socket and placed directly opposite the crosshead socket when the latter is at midstroke. The stake should be set at such a distance from the guides that the cord will lead off parallel with the guides, otherwise a guide pulley will be required. For high-speed engines it is best to adopt a form of pantograph having four joints only, as such a one is better adapted to high speed than one with a greater number of joints. Unless you have suitable tools for making a pantograph you will have considerable fun; the least variation in the location of the pivot holes will cause a failure in the action of the levers. If the thing will close up nicely and open out nicely it is all right; otherwise it is all wrong.

237. Q.—What proportion does the length of an indicator diagram bear to the stroke of an engine?

A.—Not necessarily any. The diagram is of any convenient length, to suit the taste of the one who takes it.

238. Q.—Can an indicator card be taken from an engine making 250 revolutions per minute?

A.—Yes.

239. Q.—Does the indicator card show the pressure at every inch of the stroke of the piston?

A.—Yes.

240. Q.—Is the indicator of any other use than to show the pressure in the cylinder?

A.—This is all that the indicator actually does, but from this knowledge the engineer is enabled to determine the indicated power of the engine; to adjust the valves for the best results; to detect faulty construction, etc.

241. Q.—Is there any accepted length for indicator cards, and if so, what is it?

A.—No. It is customary to proportion the length of the diagram somewhat by the rotative speed. With a slow rotative speed the cards may be taken 5 inches or upwards in length; with higher speed 4 to 4½ inches is a good length; while for still higher speeds the length may be reduced to 3 inches, or even to 2 inches.

242. Q.—Under what circumstances are the different springs of an indicator used?

A.—With fairly high rotative speed it is a good plan to use a spring marked one-half the steam chest pressure; that is, for steam chest pressure of 80 pounds use a 40 spring. With very high speed it may sometimes be advisable to use a heavier spring, and at very low speed it may be better to use a lighter spring.

243. Q.—How much, as a rule, is the motion of the pencil multiplied?

A.—Four times.

244. Q.—In taking indicator cards it is claimed by some that the atmospheric line should be drawn after the diagram has been traced; by others that it should be done first; which is correct?

A.—Our practice is always to draw the atmospheric line after taking the diagram. The reason for doing so is that the parts of the indicator are then expanded by the heat, and the atmospheric line is more likely to be in its proper position with reference to the diagram.

245. Q.—Is there a way of determining the mean effective pressure from a steam engine indicator card by finding the area of the card, and from this the required pressure? If there is, please give an explanation of the method.

A.—The most accurate and expeditious way to measure the mean effective pressure represented by the diagram is by means of the planimeter or averaging instrument; but as such an instrument is not always at hand it may by careful working be very accurately done by dividing the diagram into a number of equal parts, perpendicular to the atmospheric line, say 10, meas-

uring the hight of each division, adding these measurements together, and dividing the sum by the number of divisions. The only reason for making the number of divisions 10 is for convenience; some prefer to make the number 20, as tending to greater accuracy. The hight of each division can be measured by the scale of pounds, the measurements added together and divided by 10, the result appearing in pounds; or the measurements can be made by a scale of inches, the sum multiplied by the scale of the spring and divided by 10, giving the same result as before. As tending to greater accuracy, however, it is advisable to make the measurements continuous. For this purpose a strip is used, which is carried from one division to another, the measure of each being pricked or marked beyond the preceding one, so that the distance from the end of the strip to the last mark will represent the sum of the 10 measurements.

246. Q.—How is the clearance in a cylinder determined from the indicator diagram?

A.—The clearance space cannot be determined by an indicator card, but it is frequently required to mark this on the diagram, which may be done in the following manner: In the first place, we must determine the amount of clearance space; this is frequently difficult to do, but if we remember the meaning of the term clearance, namely, the space between the piston at the end of its stroke and the valve face, the following method will suggest itself in many cases: Suppose it is required to find the clearance space of a horizontal engine, its valve face lying in a horizontal plane. In this case the engine is placed on the dead center and the clearance space filled with water; if now this quantity has been carefully weighed, the space it occupies will be known. Water at the temperature of 60 degrees will occupy a space of 27.7 inches per pound. Say that 6½ pounds are required to fill the clearance in a 16x32-inch cylinder, the cubic inches of space occupied by the water will be $27.7 \times 6.5 = 180.05$ cubic inches. The area of a 16-inch cylinder is 201.068 square inches, and the space swept through by the piston in a single stroke is $201.068 \times 32 = 6{,}434.176$ cubic inches; hence the clearance is $180.05 \div 6{,}434.176 = .028$ of the displacement. A proportionate amount must be added to the length of the card; that is to say, we must add .028 of the length of the diagram to

it. If the diagram is 4¼ inches long, the distance to be added to the initial pressure end of the card will be $4.25 \times .028 = .119$ inch. Through this point draw a line perpendicular to the atmospheric line, and the clearance will be indicated on the card.

247. Q.—What advantages would a rotary engine have over a common reciprocating engine?

A.—The presumed advantages of an imaginary rotary engine, or, as some would say, the ideal rotary engine, are reduced weight and space occupied and higher speed of rotation. The disadvantages of the actual rotary engine would fill a big book.

248. Q.—Is there any information relating to rotary engines in any of your former publications, and where can they be procured?

A.—We have described various engines of this type at different times. The copies containing this information are not now procurable; the only way to keep up with the procession is to see each issue as it appears.

249. Q.—Is there any demand for a practical working rotary engine?

A.—We do not know of any such demand. There was no demand for the Continent of America before Columbus; there was no demand for the telephone, or for the X-ray photograph.

250. Q.—Are there any concerns manufacturing this type of engine at present?

A.—If there are we do not see their advertisements, consequently they do not wish to be known, and it would be improper to disturb them.

251. Q.—What features would have to be overcome to get the same results as from the reciprocating engine?

A.—Probably the direct rotative feature.

252. Q.—What is the greatest objection, if any, to the rotary engine?

A.—We do not know that there is one greatest objection; there are several of them, and they may be of equal magnitude, or they may vary in relative size with different types of engines. The friction of the engine is usually excessive; the packing or adjustment between the moving parts and the shell, or between the moving parts themselves, is unsatisfactory, and the wear is necessarily rapid; the leakage or blowing through is continuous, and usually large in amount, and the engines do not usually or satisfactorily use steam expansively.

253. Q.—As rotary engines work successfully on steam fire engines, why are they not used for other purposes?

A.—They are also used, we believe, to drive centrifugal pumps for wrecking purposes. They have the merit of being usually very small and light in proportion to the power developed, and for short occasional service their disadvantages do not fully assert themselves.

254. Q.—As there have been a great many patents issued on rotary steam engines, why are they not in more general use?

A.—Patenting a thing and getting it in use, unfortunately, have little or no connection. There are few, if any, patents on clothespins, and yet they are in universal use. There is no patent on the common slide-valve engine, yet it is also used everywhere. There is absolutely no merit or value in novelty alone, even if vouched for by United States letters patent.

255. Q.—I am testing a small rotary engine. I use a common platform scale, and the point where the lever bears upon the scale is 3 feet from the center of the shaft. The weight on the scales of the lever at rest is 2½ pounds, and when running at 650 revolutions per minute with throttle wide open the weight is 6 pounds. I figure that the power developed is 1.3 horse-power. Am I right?

A.—The result is practically correct. The working pressure on the scale being 3.5 pounds, then 6, the diameter of the brake lever circle, $\times$ 3.1416 $\times$ 3.5 $\times$ 650 $\div$ 33,000 = 1.299 horse-power.

256. Q.—The boiler, with the engine running at the above speed, will evaporate 1 inch of water in the glass gage in 23 minutes. The average width of the water space in the boiler is 43 inches and the length 167 inches, and the evaporation, according to my figures, is about 10 cubic feet per hour. Is the engine using more water than should be required for the brake horse-power?

A.—As 1 inch of water is evaporated in 23 minutes, the evaporation per hour is 23 : 60 :: 1 : 2.608 inches, and then 43 $\times$ 167 $\times$ 2.608 $\div$ 1728 = 10.83 cubic feet, and, as water at the temperature corresponding to 70 pounds steam pressure weighs 56.7 pounds per cubic foot, the total weight will be 10.83 $\times$ 56.7 = 614 pounds, and 614 $\div$ 1.3 = 472 pounds of water per horse-power hour. A common slide-valve non-condensing engine can be run upon one-tenth of this water, and we do not know of anything but a rotary engine that could get rid of as much.

257. Q.—Where can I procure a medium-priced book or books on rotary as well as reciprocating expansion engines?

A.—There are innumerable books on the steam engine, of all sizes and prices, so that we cannot well recommend any single book. Consult publishers' catalogs, which may be had for the asking.

258. Q.—Will a pump use more steam if it exhausts in the water than if it exhausts in the air?

A.—Steam pumps are sometimes arranged to exhaust into the suction, by which it is claimed steam is saved. If you mean exhausting below the surface of the water, as in a pond or reservoir, it will require more steam to operate the pump.

259. Q.—Is it good practice to pump the water from the condensed exhaust steam back into the boiler?

A.—Yes; provided that great care is taken in oiling the cylinders, so that the exhaust steam will carry very little oil with it. The oil used for cylinders should be a mineral oil, and not animal oil; if the latter is used, we should not pump the water from the condensed exhaust steam back into the boiler unless the exhaust steam is run through a separator, of which there are several in the market.

260. Q.—Is it better to use the exhaust steam from an engine in the water heater and then in the pipes for heating purposes, or the reverse?

A.—We prefer to let the exhaust steam pass into the water heater first, and then use the remainder for heating purposes.

261. Q.—What are the relative wearing qualities of malleable iron and cast steel for the purpose of making cast links for reversible engines that have to be reversed suddenly under full speed?

A.—We have found that the cast-steel links wear a good deal better than malleable iron castings.

262. Q.—What size hole should I bore in the stuffing box of an ordinary fast-running engine with rod 2 inches diameter, in order to insure a good steam-tight fit without cramping rod, or producing any unnecessary friction?

A.—You cannot get a steam-tight fit in this way without the use of packing, unless you adopt some such plan as is used by Professor Sweet in his Straight Line engine, which is a very long bush of soft metal, which the rod passes through. Where ordinary packing is to be used, the hole should be 1-32 inch larger than the rod, though if it is desired to have it as close as

possible, and pains are taken to do accurate work, it may be somewhat closer than this.

263. Q.—What will clean burnt oil from the cylinder head of an engine, and is there anything better than paraffine to keep finished work bright?

A.—Strong lye water is good for cleaning the cylinder head. If a horizontal engine, take off the head and lay it down where you can cover it over night with waste saturated with lye water. Use a small package of lye to a pail of water. The paraffine is probably as good as anything for finished work.

264. Q.—We have in shop two piston rod ends which are tapered, the only difference being that one has a collar against which the piston can be driven, while the other has not. In discussing the matter with my superiors I have maintained that the collar was necessary, while they claim it is not. Their only reason for using no collar so far has been that it is easier to make a good fit without the collar. I propose making a fit which will allow the collar to come within 1-16 inch of the piston while cold, then heat the piston and shrink it on. I am told that the oldest and best engine builders do not use collars. If this is so, perhaps you can tell me why. The taper in this case is 3 inches per foot, which makes the tapered part so short that it leaves a straight bearing through the piston.

A.—The reason for making the ends of the piston rods tapered is to obtain a perfectly tight fit, and when the taper is comparatively slight there is not much difficulty in making it so. Another reason for making it tapered is that the rod can be withdrawn with greater ease than when the ends are straight; this is probably of greater importance in marine engines than in locomotives or stationary engines. In many marine engines, when the taper extends the whole depth of the piston, it is ¾ inch per foot, and in locomotives only about half that amount. With slight tapers there is danger of splitting the pistons by the wedging action, and therefore the piston rod is turned with a shoulder of 1-16 to ⅛ inch deep, the latter being suitable for comparatively large piston rods; this shoulder will also allow the piston rod to be slightly re-turned when necessary, without interfering with the taper. Although the necessity of shoulder is advocated by many builders, collars are generally avoided. A

taper of 3 inches per foot and allowing this taper to continue until the section of the rod is three-fourths of that of the body, and then turn the remaining part cylindrical, is also recommended by many engineers in cases where the ease of withdrawal of the piston rod is of importance, because even with the liberal taper of ¾ inch per foot there is sometimes considerable trouble experienced in withdrawing the rod after a few months' work. These ends also generally have a shoulder.

265. Q.—In keying a crank disk of a steam engine to the shaft some builders drive the key through the counterbalance, while other builders cut the keyway through the crank. Which is the best way?

A.—Keyways will always weaken the disk more or less, and since that part of it which acts as a counterbalance is the strongest part, we prefer to cut the keyway there.

266. Q.—I have an argument with an engineer in regard to the governor on an engine. The governor has two balls weighing about 15 pounds, and makes about 35 turns per minute. I claim that if we make the balls' weight 5 pounds less we can run it at a higher rate of speed and hold the engine at the same speed. Who is right?

A.—You are wrong. Decreasing the weight of the balls will affect their power of overcoming the friction in the various connections of the governor; a decrease or an increase of the weight of the balls, leaving the friction out of account, will in nowise affect the speed of the engine. If you wish to increase the speed of the governor without changing the speed of the engine, you must shorten the governor arms.

267. Q.—Should an engine cylinder be counterbored so that the packing ring, or only the follower, will run over the shoulder, and how much should either run over in cylinders about the size of ordinary locomotive cylinders?

A.—One of the ends aimed at in counterboring engine cylinders is to prevent wearing a shoulder, against which the packing may strike when the length of rod is slightly changed in lining up; hence the packing should travel over the shoulder. From ⅛ to ¼ inch is the distance the packing is usually allowed to travel past the shoulder; in some instances more. The distance should be determined to some extent by the kind of packing

used and the amount of clearance between the piston and the cylinder head. With narrow packing, if the cylinder is counterbored too far, there is danger that as the length of the rod changes in keying up the ring will drop into the counterbore. The counterbore should never be so deep but that the piston will strike the head before this can occur.

268. Q.—In packing a flange or cylinder, when red rubber, or any other rubber, is used, should oil or grease be applied?

A.—No; the surfaces should all be clean.

269. Q.—Can you recommend any of the sulphus compounds for leveling up the bed of a steam engine? What is the best way to use it?

A.—We have used common stick brimstone for years without a single instance of failure. Our practice has been to level up the engine by using small iron wedges, bringing the hold-down bolts to a fair bearing. Then cut some wooden strips to lay up close to the frame all around, and putty up any slack pieces there may be around the strips. About once in 18 inches leave a hole for pouring the brimstone, building up a head or riser of putty or fireclay. Melt the brimstone in an iron kettle over a *very slow* fire, and when it is quite limpid pour it. It will run very freely, and when hard the hold-down bolts can be set down firmly. In melting the brimstone great care must be taken that it does not take fire. Have ready some bagging, or equivalent, and if it accidentally takes fire remove the kettle from the fire and smother it by covering it over. As before stated, the fire must be a slow one. If the brimstone becomes too hot it gets thick again, the remedy for which is to set it off the fire to cool. All holes must be carefully stopped, as the brimstone will run through a very small aperture. Brimstone is but slightly affected by temperature, and if there is reasonable bearing surface it is almost equal to a solid stone bearing. In hundreds of cases we never knew it to fail when properly used. It can be used on stone, brick or wood.

270. Q.—What is the proper weight for the flywheel for an engine with 18x24-inch cylinder, 135 revolutions per minute, throttling governor, boiler pressure 90 pounds, developing 175 horse-power? The engine drives wood-working machinery. Would like a rule that will give at least approximate results.

A.—The rules for flywheels are as numerous as the builders

of engines and the writers on the subject. The mathematical principles entering into the question are well understood, but the trouble is that a constant for the degree of fluctuation to be allowed enters the formula, and very little accurate knowledge exists regarding the value of this constant for different classes of work. The best treatment of this subject of which we have any knowledge was published in our columns September 7 and 14, 1893, by Emil Theiss, the resulting formula being:

$$W = i \frac{d \times IHP}{v^2 \times n}$$

in which

W = weight of rim in pounds;

i = a coefficient depending on point of cut-off and piston speed;

d = the coefficient of steadiness (being the constant mentioned above);

IHP = indicated horse-power;

v = velocity of rim in feet per second;

n = number of revolutions per minute.

Assuming the cut-off to be at half-stroke, the value of i, according to the tables of Mr. Theiss, is

$i = 170{,}000$.

For your class of work we should judge that a suitable value for d would be

$d = 50$.

We have also

$v = 47$;

$n = 90$;

$IHP = 175$.

Substituting these values gives:

$$W = 170.000 \frac{50 \times 175}{2.200 \times 93} = 7.500 \text{ pounds for the rim.}$$

This would give nearly 10,000 pounds for the entire wheel, and we should aim at that figure. We are acquainted with a line of 18x30-inch engines which have 12,000-pound wheels, and they have given excellent results.

271. Q.—What is the rule for finding the weight of a flywheel for an engine 18x24 inches, at 135 revolutions per minute, boiler pressure 90 pounds?

A.—The practice of engine builders varies so widely regarding flywheels that there can be said to be no rigid rule applicable to the case. Professor Barr, in his paper entitled "Current Practice in Engine Proportions," gives the following for the weight of the flywheel rim:

$$\left.\begin{array}{ll} \text{Mean} & \ldots\ldots 1{,}200{,}000{,}000{,}000 \\ \text{Maximum} & \ldots 2{,}000{,}000{,}000{,}000 \\ \text{Minimum} & \ldots\ 650{,}000{,}000{,}000 \end{array}\right\} \times \frac{H\,P}{D^2 \times N^3}$$

Here $H\ P$ is the nominal horse-power, D the diameter of the rim in inches, and N the number of revolutions per minute. It will be noticed that the maximum result by this formula will be more than three times as large as the minimum. Taking the mean and assuming the nominal horse-power of the engine to be 150 and the diameter of the rim of the wheel 10 feet, we have:

$$1{,}200{,}000{,}000{,}000 \times \frac{150}{120^2 \times 133^3} = 5{,}080 \text{ lbs.}$$

For other diameters of rim the weight will, of course, be inversely as the diameter.

272. Q.—I am a machinist with over ten years' shop experience, and the last two years I have been employed as stationary engineer, and am quite familiar with the steam engine. I understand perfectly well geometry and algebra. Do you believe that by studying books treating on the steam engine I could prepare myself to pass an examination for an engineer's license? If so, what books should I study?

A.—With the experience you have had, and by studying books relating to steam engineering, you should have no difficulty in passing a creditable examination.

Pumps and Hydraulics.

273. Q.—Supposing I have a pump that will discharge 100 gallons a minute and throw it 100 feet high. The piston speed is 100 feet per minute, and the steam pressure 100 pounds, throttle valve wide open. At what hight will the same pump throw the water when running with a piston speed of 75 feet per minute, and discharging 75 gallons per minute?

A.—The hight to which the water will be thrown will vary under the given conditions as the square of the piston speed. The square of 100 is 10,000, and the square of 75 is 5,625; hence we have: 10,000 : 5,625 :: 100 : x. This gives a value of 56.25 for x, which is the hight to which the water will be thrown with a piston speed of 75 feet per minute.

274. Q.—I have to attend to some two-throw pumps which work very badly and wear out the gearing very quickly. The depth of the well is 160 feet; the air vessel is at the top of the well; stroke of pump, 9 inches; diameter of barrel, 5 inches. I advised that the air vessel should have been placed as near to the pump as possible, and ordered this to be done. In the meantime an old-established firm who made the pump were consulted, and informed us that it is quite immaterial whether the air vessel is next to the pump or not, and that it is generally placed near the pump for convenience; consequently my order was countermanded, and I was further sat upon by being told that the practical view agrees with the theory. Who is right?

A.—The information given by the manufacturers needs considerable modification. Although a foot or two in the position of the air chamber from the pump does not make any practical difference, the position is by no means a matter of convenience. On general principles the air chamber should be as close as possible to the pump, because when the air chamber is placed at too great a distance from the pump considerable time will be required to overcome the inertia of the volume of water between the pump and air chamber before the effects of the latter can be

felt, and consequently the pump cannot work as smoothly as when the air chamber is placed near it. Of course, the unsatisfactory working may be largely due to the general design.

275. Q.—I am laying a quantity of cast-iron water pipe, 12 to 30 inches diameter, on a surface of flat, coarse gravel. The intention is to fill the flat to the depth of about 5 feet with cinders from bituminous coal. Will this give trouble by causing the pipe to corrode?

A.—We should not use these pipes without dipping them in coal pitch varnish, otherwise the pipes may give considerable trouble in time. Of course, before the varnish is applied, the pipes must be thoroughly dressed and made clean, free from the earth and sand which cling to the iron in the molds, hard brushes to be used in finishing the process to remove the loose dust. Great care must also be taken to have the pipes entirely free from rust when the varnish is applied. If the pipe cannot be dipped immediately after being cleansed, the surface should be oiled with linseed oil to preserve it until it is ready to be dipped. Every pipe must attain a temperature of 300 degrees Fahr. before it is removed from the vessel of hot pitch. It may be slowly removed and laid upon skids to drip. Pipes 20 inches in diameter and over will require to remain at least 30 minutes to attain this temperature.

276. Q.—How is a hydraulic ram constructed, and how does it work?

A.—The hydraulic ram is a self-contained and automatic pump operated partly by the pressure of a column of water in a pipe, and partly by the stored-up energy acquired by the intermittent motion of the column. In its simplest form it consists of a main pipe placed on an incline leading water from a spring or reservoir at the upper end of the pipe to an air chamber attached to the lower end of the main pipe; this air chamber is connected to a tank placed somewhat higher than the spring or reservoir. To the lower end of the main pipe another smaller pipe is attached extending downwards, with a cock at the lower end, from which water is drawn for, say, domestic purposes. When this cock is opened, the water in the small and main pipes is put in motion, and acquires a velocity due to the head; as soon as the cock is closed the momentum of the column of water opens a valve in the air chamber, and the water rushes

into this chamber. This effect takes place every time the cock is used, and as water is drawn from it at short intervals for household purposes, an abundance of water will be raised in the tank.

277. Q.—What power is there in 200 gallons of water per hour at 50 pounds pressure, not allowing for friction, and assuming that we get 100 per cent.?

A.—To find the power of a fall of water, we "multiply the volume in cubic feet per minute by 62.5 (the weight of a cubic foot of water), and this product by the vertical hight of the fall in feet." Two hundred gallons per hour is equal to 2⅔ gallons per minute, and occupies 845.46 cubic inches, or about .5 of a cubic foot, which, multiplied by 62.5, and again by 108 (this hight of water corresponds to a pressure of nearly 50 pounds), we obtain as a result 3,850 foot-pounds, or about 1-10 horse-power.

278. Q.—How are lead joints made in 5-inch or 6-inch cast-iron water pipe?

A.—Place the pipes in position upon blocks, so that the small end of each pipe is in the center of the large end of the next piece of pipe. Roll up a loose rope of tow, lap it around the small pipe and press snugly into the end of the large pipe. The object of the tow is to prevent the lead from running into the interior of the pipe. A roll of putty, or tempered clay, is pressed firmly around the opening between the small and large pipes, to keep the lead from running to waste. An opening is left in the clay at the top of the pipe, and melted lead is poured in until the cavity between the tow and the putty is completely filled. Next, the putty is removed and the lead is caulked until the joint is water-tight. Square-end steel tools are used for caulking, shaped like those used to drive keys out of pulleys and gears. The value of the joint depends upon the manner in which the lead is made to fill the space between the two pipes. When the lead cools, after being poured, it shrinks and leaves a space between the lead and the outer pipe. By "tamping" or caulking the lead, it is upset until every portion of the space between the pipes is completely filled.

279. Q.—I wish to bring soft spring water, for household use, 3,000 feet, under 175-foot head. What kind of pipe can be used, that the

water may be pure and the pipe durable? What solvent will remove the soft, pasty iron rust which has partly filled a 1-inch plain wrought-iron pipe now laid?

A.—Prof. O. H. Landreth, Union College, Schenectady, N. Y., answers as follows: "(1) If the pipe is to be laid deep enough in the ground to be permanently wet, as it probably will be, to place it below frost line, bored wooden pipe would meet the requirements; but under the head stated, the thickness of shell necessary would probably make the cost in excess of properly prepared iron pipe. Galvanized wrought-iron pipe will resist corrosion well for a time, but ultimately will succumb to the action of the oxidation under the thin coating of zinc. Plain black wrought-iron pipe, thoroughly coated inside (and preferably also outside) with a preparation of coal-tar pitch and asphalt, such as is used to coat cast-iron water pipes, will not be affected by soft water if the coating is well done. For the length needed, probably any of the manufacturers of wrought-iron pipe would take a special order for the asphalt coating. (2) There is probably no solvent within reach, financially, that would start the rust coating without corroding the shell of the pipe in places before the rust was removed in others. Kerosene would probably loosen and disintegrate the rust, but there is doubt as to whether there would be enough erosion in the running stream of water afterwards to remove the loosened rust; nothing short of a trial will tell. The kerosene may be introduced by draining the pipe for several hours and then running in a few gallons of kerosene, then allowing the pipe to fill very slowly with water—from the lower end, if possible—which will float the kerosene slowly through the entire length. The water should be admitted very slowly, not faster than 4 or 5 gallons per hour. If rapid flushing of the pipe with the full head of water afterwards brings out loosened rust, one or more repetitions of the treatment would be warranted."

280. Q.—I elevate 730 pounds of water 40 feet for every pound of coal consumed in the boiler furnace. Is this economical pumping?

A.—Whether this is economical pumping or not depends upon how much is pumped, and with what kind of pumping engines it is done. The work amounts to 2,920,000 foot-pounds per 100 pounds of coal. The highest record for pumping that we know

of was made by the triple-expansion pumping engines at Milwaukee, which gave a duty of 143,306,000 foot-pounds per 100 pounds of coal, and the Corliss Pawtucket pumping engine, one of the most famous in America, gave a duty, on test, of 138,126,000 foot-pounds per million British thermal units; 1,000,000 British thermal units being roughly what may be expected from 100 pounds of coal. Compared with such performances, your pumping is, of course, very far from economical, and yet it may be as economical as it can be with your particular pumping plant and with the amount of pumping you have to do, particulars regarding which you do not give.

281. Q.—If a solid be immersed in a liquid will not the upward tendency be equal to the difference in weight between the solid and the volume of liquid it displaces? It being supposed that the liquid is of a greater specific gravity than the solid.

A.—The vertical upward force called the buoyant effort is equal in amount to the weight of the liquid displaced.

282. Q.—Suppose now that the bottom of this solid is a plane surface and is in contact with the bottom of the tank containing the liquid, and in this position the sides of the solid are in a vertical position, what will be the upward force?

A.—If under the given conditions the lower surface of the solid fits the bottom of the tank so as to prevent any liquid from getting between them, there will be no buoyant effort.

283. Q.—We have a stand-pipe tank, 100 feet high, 15 feet in diameter, and we wish to know which plan of filling this will cause the least loss by friction—that is, to run a pipe 3 inches diameter to the full hight of the stand pipe and discharging at the top, or to pump the water into the tank 2 feet from the bottom.

A.—The plan of pumping to the top through the 3-inch pipe will cause more frictional loss; such loss increasing with decreased diameter of pipe where the same quantity of water is delivered. A more serious loss by the pipe arrangement might be, however, from the fact that by it water pumped into the tank must all be raised to the maximum hight of 100 feet, whereas by pumping into the bottom, the head pumped against is never greater than the actual hight of the water in the stand pipe.

284. Q.—What can I put on the outside of cotton hose to keep it from decaying?

A.—A manufacturer of cotton hose says that the treatment of the hose during the manufacture is such as to prevent decay, and nothing can be used afterwards without injuring the rubber.

285. Q.—What size of hole in the nozzle will throw the water through the greatest distance? The hose is ¾ inch diameter, pressure about 50 pounds per square inch.

A.—In practice the general proportions of the nozzle are: Length, from 6 to 10 times the diameter of the hose, and the outlet end of the nozzle is one-third of the diameter of the hose. According to this, you will need a ¼-inch hole in the nozzle.

286. Q.—Are leather packings for pumps for hydrostatic presses lubricated; if so, what lubricant is used?

A.—After the leather packing has been pressed to the desired form and then dried by a moderate heat, and finally trimmed, it is immersed in blood-warm beef tallow, and when thoroughly soft the surface is wiped off and the packing placed in the recess prepared for it. The general treatment of the leather for the packing is as follows: It is soaked over night in clean water so as to make it soft and pliable. It is then cut to the required shape for compression in a cast-iron form. The process of compression must be slow. After compression the leather is dried by a moderate heat, then removed from the cast-iron form and carefully pared, after which it is immersed in the beef tallow as stated above. Failures result with poor leather, or leather of uneven thickness, insufficient time in soaking, and molds of improper shape, which are liable to break the grain of the leather, causing it to rot rapidly by water being forced through it by the pressure to which it is subjected.

287. Q.—We have been trying to syphon water from one well to another 350 feet apart; the water in one well is 10 feet higher than in the other. We have been using it for a month, and our difficulty is that as soon as the water in the wells approach a level with each other, the syphon stops, and will not start again until the pipe is opened and refilled. What is the reason for this? The pipe does not leak.

A.—The reason for the stopping of the syphon when the water approaches the same level in both wells is that there is not a sufficient head in one of the wells to overcome the friction of the water in the pipe. Also, when the velocity of the water in the pipe is low, air is liable to collect in the pipe and stop the

flow of water. It must not be expected that after a syphon has ceased to work it will start by simply lowering the water level in one well; the syphon must be refilled before it can start.

288. Q.—What is the practical rule for the size of supply pipe for the cylinders of hydraulic hoists?

A.—Practice is quite divergent, owing to the great variety of conditions. In some experiments, a pipe area of 1-150 part of the ram was found to give a ram speed of 15 feet per minute with 600 pounds pressure, and a speed of 25 feet with 1,200 pounds pressure. With a pressure of 1,000 pounds, a pipe diameter of 1-100 to 1-150 of the ram fulfills ordinary requirements of speed when the water discharges through another pipe. Where the same pipe is used for admission and discharge, a pipe diameter of 1-30 to 1-50 of the ram is necessary to give reasonable speed to the return movement. Some designers habitually allow an excess of 40 or 50 per cent. in the size of the ram over that actually required to lift the load, in order to provide sufficient difference in pressure at the two ends of the pipe to provide a prompt movement. With your ram of 6 inches diameter and pressure of 300 pounds, we would use ⅜-inch pipe, if the same pipe is to act both for admission and discharge.

289. Q.—What is the horse-power of a round column of water, 2 feet in diameter, falling from a hight of 25 feet?

A.—The question in this form has no practical meaning, as the speed of the water in the pipe, or its quantity in gallons, is necessary. A stream falling freely could not have a diameter of 2 feet at more than one point, as the velocity increases as the water descends, and the diameter of the column would therefore grow smaller. If you assume a stream of this kind, having a diameter of 2 feet at its lower end, its power could be determined thus: If v = velocity in feet per second, h = hight fallen through in feet, then $v = \sqrt{h}$. In this case $h = 25$, therefore $v = 8\sqrt{25}$, $= 40$ feet per second. A stream 2 feet in diameter, flowing 40 feet per second, would discharge $3.14 \times 40 = 94.2$ cubic feet $= 5{,}890$ pounds per second. Now,

$$\frac{\text{pounds per second} \times \text{distance fallen}}{550} = \text{horse-power},$$

$$= \frac{5{,}890 \times 25}{550} = 268.$$

In practice the quantity of water is first determined, and the pipe is proportioned to carry this water, with such loss as is allowable under the circumstances.

290. Q.—What power is there in a stream of water flowing through 300 feet of 1-inch pipe with 40 feet head? Would there be enough power to run four 16 candle-power lights? What would be the increase of power if the pipe was changed to 2 inches diameter? Is there any simple rule to compute this?

A.—There is no simple rule. Using the table of the Pelton Water Wheel Company as a basis, we would figure it something like this: Allowing the water to flow through the pipe at the rate of 1 cubic foot per minute, the loss of head in the pipe itself would be about 15 feet, so that we would have only 25-feet head for the water when delivered. As a cubic foot of water weighs 62.35 pounds, we would have $62.35 \times 25 = 1{,}557$ foot-pounds, of which. perhaps, one-half, or 778 foot-pounds, might be developed by the water-wheel and connections actually employed. As a horse-power is 33,000 foot-pounds per minute, and as a 16 candle-power lamp, roughly, takes one-tenth of a horse-power, or 3,300 foot-pounds per minute, the power to be obtained from the water above would probably thus be less than one-quarter enough for one 16 candle-power lamp. With a 2-inch pipe, and other conditions as above, there would probably be about power enough for one lamp.

291. Q.—We have difficulty in keeping tight a joint in the supply pipe leading from a tank to a hydraulic crane. When the water is shut off the water hammer tends to loosen the joint. We have a relief valve on this pipe, but it does not do much good. Can we put an air chamber on this pipe, and will it help us any? the supply pipe is 6 inches diameter.

A.—An air chamber will help you. It should contain a volume of about 3 cubic feet.

292. Q.—What is meant by the total head of a centrifugal pump? Is it the suction head plus delivery head plus velocity head?

A.—We would understand it to mean the delivery head plus the suction head, or the actual vertical lift from one level to the other. If the velocity head were included, then the friction head should also be added.

293. Q.—How high is it practicable to lift water with a centrifugal pump?

A.—We would say 40 feet, not that that is the limit, but that the efficiency falls off rapidly above that. In California centrifugal pumps are successfully worked against a head of 100 feet. L. Dumont, Paris, shows four centrifugal pumps taking water from one to the other successively, all driven by one electric motor and raising water 40 to 60 meters, or, say, 130 to 195 feet, and by this "tandem" arrangement high lifts are attained with fairly good efficiency.

294. Q.—What kind of packing should I use on a pump for hot water; that is, on the plunger?

A.—Any kind of packing, fibrous or flexible, that is suitable for steam piston-rod stuffing boxes should do for hot-water pump plungers. If a fibrous packing, such as flax, is used, do not oil the packing before putting it in. The oil prevents its soaking up and filling with water, and makes air leaks possible.

295. Q.—How would you construct the piston and packing for a hydraulic machine, mercury being the fluid, so as to prevent any leakage of mercury with a pressure of 40 pounds per square inch?

A.—We should use a plain cast-iron ram, having a diameter nearly equal to that of the cylinder, and use leather cup packing fitted into a cell made for its reception in the interior of the cylinder; in fact, we should adopt the construction of an ordinary hydraulic press, as illustrated in many text-books on mechanics, or in any elementary treatise on physics.

296. Q.—C has a well delivering 700 gallons of water per minute at 61 degrees temperature. His shop, 98 feet long, 36 feet wide and 13 feet high, is often as hot as 92 degrees, and he wants to know if the water cannot be made to cool the air.

A.—The shop contains 46,000 cubic feet of air, weighing 3,500 pounds. The specific heat of air at constant pressure is .2375. If the air is to be cooled 20 degrees, $3{,}500 \times 20 \times .2375 = 16{,}600$ heat units must be extracted from it. Seven hundred gallons of water weigh 5,800 pounds. If the water is to be warmed 10 degrees, 58,000 heat units per minute are available: $\frac{58{,}000}{16\,600} = 3\frac{1}{2}$, approximately. In other words, the water would cool the entire body of air in the shop $3\frac{1}{2}$ times per minute, which is far in excess of the requirements, as when once cooled

it would be easy to keep it so. To get the apparatus to work, however, would not be so easy. A mere tank, as you suggest, would not have enough cooling surface. The transmission of heat through plates between water and air in motion is at the rate of about 5 heat units per square foot per minute. To carry 58,000 heat units per minute would require $\frac{58,000}{1\frac{1}{2}} = 44,000$ square feet of surface. This, again, is largely in excess of the requirements after the shop is cooled down. The actual surface necessary is not easy to get at, but the above figures will show that the apparatus for surface cooling would be a formidable affair. Spray cooling would be more promising.

297. Q.—When you get a vacuum of 15 pounds and keep on pumping, what takes place? It seems to me that you ought to get more vacuum.

A.—Your difficulty seems to come from a failure to understand clearly just what a vacuum means. It actually means nothing, and when you have by pumping obtained a space in which nothing exists, then you cannot pump anything out of that space; and though the pump may keep on going through its usual motions, there will be nothing to lift the valves from their seats, and no more complete or more perfect vacuum can be obtained.

298. Q.—What should be the relative sizes of steam and water cylinders for steam pumps?

A.—The sizes depend altogether on the service required. Where there is a head or pressure against the pump piston the steam piston must be large enough not only to balance the resistance due to head pressure, friction, etc., but to speed up to a proper velocity. While calculations can be made to determine the proper sizes, experience is the best guide, as there are many things that can hardly be enumerated that affect the satisfactory working of a pump.

299. Q.—Is it necessary to have a valve in the drive pipe of a hydraulic ram so as to regulate the pressure?

A.—We have not seen a valve used for this purpose, and have some doubt as to its advantage; the pressure depends on the hight of water in the spring or source of supply. A gate may be used with advantage at the inlet of the drive pipe to regulate the supply of water.

300. Q.—Is there any reason why a drive pipe should not be brought down on a straight line instead of running it zigzag, which has been done in some cases? The claim is that the momentum is too great when the drive pipe is straight.

A.—It might in some cases be well to use the "zigzag" course to lengthen the pipe and increase the momentum, instead of diminishing it.

301. Q.—We are pumping to a reservoir, giving us 120 pounds pressure. A distant district which we must supply will only have 60 pounds, and they require for fire protection 80 pounds. This necessitates that we put in an auxiliary pump. Which would be the cheapest in the operating expense—first, to put a pump at the reservoir, where it would have little or no pressure on the suction, or, second, place the pump where it would have about 60 pounds on the suction? We would save about 2 miles of 16-inch pipe by the second plan, if it is practical.

A.—The second plan is practical and we prefer it, because it will not only save 2 miles of 16-inch pipe, but it will also require a smaller pump. The cost of fuel saved in running this pump will, in all probability, be greater than the extra cost for labor to run it, unless the quantity of water to be delivered to the distant district is very small. On the whole, the second plan seems to us to be the best, and operating expense will be less.

302. Q.—I notice that all duplex pumps have four steam ports. Please give the reason for using that number of ports.

A.—In examining the slide valve for this class of pumps you will find that the valves have only a very small amount of lap, or none, thereby allowing the steam to follow the piston nearly throughout the whole stroke. This is necessary, because these pumps have no flywheel to control the fluctuations of the steam pressure when the steam is used expansively, as it would be when the valve has outside lap. The valves are arranged to cut off steam near the end of the stroke, and open the exhaust at the same time, or nearly so, preventing a certain amount of compression necessary for resisting the stored-up energy in the reciprocating parts. Now, the advantage of two ports at each end of the cylinder will be seen. The outer port is used for admitting the steam, the inner port is used for exhausting; and, the latter port being covered by the piston when the steam port

closes, there is no escape for the steam, and the required amount of compression will be obtained.

303. Q.—How is the size or area of an air chamber found for a pump, say a double-acting pump, with rams 8 inches diameter and 18 inches stroke?

A.—There is no rule and no fixed practice that we know of in this matter. The air chamber cannot be too large, and if of a capacity equal to, say, four times that of a single stroke of the pump, it should usually be large enough. Thus, the capacity per stroke of the pump cylinder would be $8^2 \times .7854 \times 18 \div 1728 = .523$ cubic feet. Then, an air chamber with a capacity of 2 cubic feet would be as large as would usually be provided.

304. Q.—We have a double-acting steam pump, on which the air chamber seems to lose its power after running a time. Can you suggest the cause and a probable remedy?

A.—The disappearance, partial or total, of the air in the air chamber does not necessarily imply a leaking out of the air. It is not an unusual experience to find the air disappearing from the air chamber, especially when working under considerable head. When air is confined under pressure and in contact with water, the water will absorb some portion of the air, unless it is already fully aerated. Every time the pump is started it is always possible to know that the air chamber is full of air by having two pet-cocks, one at the top and one at the bottom of it, and having them open until water ceases to flow out of the lower one, and then closing both before starting the pump. When the full pressure is on the air in the chamber is, of course, compressed to a very small portion of its original volume, so that a larger air chamber is required for high-pressure pumping than for low-pressure. The disappearance of the air by absorption may be compensated for, and the air chamber may be kept full of air by having a pet-cock in the suction pipe to admit, by a little opening, a little air, which will be carried along with the water and may be expected to collect in the air chamber. Such admission of air will, of course, impair the suction, but if the water is not drawn more than a few feet no trouble should ensue. This admission of a little air into the suction is quite frequently done, and in many cases, especially with electrically driven pumps, the entire action of the pump is made smoother and easier by it.

305. Q.—What is the proper method of calculating the duty of a pumping engine in foot-pounds per 1,000 pounds of steam or water? For instance, it is required to pump 6,000,000 gallons of water per 24 hours against a head of 220 feet and develop a duty of 95,000,000 foot-pounds for each 1,000 pounds of water fed to the boilers. And again, it is required to raise 6,000,000 gallons of water 150 feet every 24 hours and to develop a duty of at least 100,000,000 foot-pounds of work in water delivered per 100 pounds of coal fired to the furnace.

A.—The ultimate work of a pump is simply the lifting of a weight, and when we know the weight of water lifted in pounds and the hight to which it is lifted in feet, or the head against which it is lifted, their product is the foot-pounds of work realized. Thus, in the first case cited, the weight of a gallon of water being 8.3216 pounds, we have $6,000,000 \times 8.3216 = 49,926,600$ pounds as the total weight of the water, and as this is lifted 220 feet, the work done is $49,929,600 \times 220 = 10,984,512,000$ foot-pounds, and this divided by the 95,000,000 and quotient multiplied by 1,000 would give the number of pounds of water to be fed to the boilers in 24 hours for raising the 6,000,000 gallons of water in the same time under the assumed duty. $(10,984,512,000 \div 95,000,000) \times 1,000 = 115,600$ pounds of water. In the second case we have the same weight of water raised 150 feet, or, as before, $49,929,600 \times 150 = 7,489,440,000$ foot-pounds, and as the assumed duty is 1,000,000 foot-pounds per pound of coal, then 7,489 pounds of coal would be required for the 24 hours.

306. Q.—A and B have an argument about the lift of a pump. A has a large Dean steam pump. The water supply is from a creek. The ordinary lift of the pump is 25 feet. When the creek gets very low the lift is 29 feet. At this lift the pump must be run quite slowly. If run at the same speed as when lift is only 25 feet, the pump loses water and jumps. A claims that if a weak spring, just strong enough to close the suction valves promptly, was put on the suction valves the pump would work better at the 29-foot lift than if stronger springs were used. B says it will not. Is A right or wrong, and why?

A.—We referred this question to the makers of the pump mentioned, who replied as follows: The functions of the springs on the water valves of a pump are twofold, one to keep the valves

from opening too far and so cause an unnecessary loss from slip when they close, and, second, to cause the valves to close promptly when the current of fluid ceases to flow through them as the pump reverses. The proper tension of the springs depends upon the velocity with which the fluid flows through the valves. The adjustment of this tension is more important on suction valves than on discharge valves, as the proper filling of the pump cylinder depends more largely on the action of the suction valves. If the fluid runs to the pump under a head, or if the velocity of the fluid through the valves is high, more tension is required to keep the valves in proper position and to close them promptly than if the supply has to be lifted by suction or if the velocity is low; for in the former case the springs have to overcome the conditions, while in the latter case the conditions assist the action of the springs. On very high suctions like that of 29 feet, nearly the total suction power of the pump is required to simply raise the fluid, so that heavy springs cannot be compressed nor a high velocity maintained through the valves. Under these conditions it will be readily seen that, of the force available to compress the springs and to maintain the velocity of the flow, as much as possible should be utilized for the latter purpose, as the capacity of the pump depends upon the quantity of fluid that can be drawn through the suction valves. To this end the springs should be as light as will permit them to properly perform their function under the described circumstances. If the springs in the pump referred to are of the standard tension, A is undoubtedly correct, for force is wasted in compressing these springs, which could with greater advantage be utilized in maintaining a higher velocity of the fluid through the valves, and so increasing the capacity of the pump.

307. Q.—A has a horizontal hydraulic cylinder with one piston, and admits water under pressure at one end of the cylinder. B has the same size cylinder and the same pressure, but has two pistons, admitting the pressure in the center of the cylinder, and forcing the pistons towards the ends. B claims that he can develop twice the power with his arrangement that A can develop with his, while A denies this. Who is right?

A.—If the water is admitted to the cylinders in each case so that the pressure is maintained during the movement of the

pistons, or so that the average pressure throughout the stroke is the same in all cases, and if each of B's two pistons move at the same rate as A's one cylinder, the power developed by B's arrangement will double that developed by A's. These conditions can be developed in practice.

308. Q.—What is the advantage, if any, of transmitting power by ropes?

A.—Generally speaking, it is doubtful if there is any advantage, except in cases where gears or belts would be inadmissible, and in England, where rope driving has been largely used as a substitute for gears, they are returning to gears, as formerly.

309. Q.—Is it true that at great depths the water of the sea is so dense that if an ironclad ship were to sink it would never reach the bottom?

No. This idea results from a confusion of density and pressure. At great depths the water of the sea is, of course, under tremendous pressure, but its density or weight per cubic foot is but very slightly increased over that at the surface, and a foundered ironclad would undoubtedly go to the bottom.

Pneumatics.

310. Q.—I have a direct steam cotton press with cylinder 25 inches diameter by about 7-foot stroke. The press is about 100 feet from the boiler, with 1½-inch steam pipe. In baling cotton the cylinder is filled with steam every 2½ to 5 minutes, and on the last charge of cotton it is held in the cylinder from 2 to 15 minutes. Now, this thing wastes too much steam. I have almost decided to build a tank near the press and put in a steam pump, with about 3-inch discharge pipe into the cylinder, and to use cold-water pressure instead of steam, as I believe it would be more economical of steam, although it might be too slow and could not do the work required. How would an air compressor do?

A.—An air compressor would not do. That is, it could be made to work all right, but would use, perhaps, double as much steam as when the steam was admitted direct to the cylinder. Saying nothing of the loss by the condensation of the steam, the same volume of air would be required to fill the press cylinder as of steam, and, as a general rule, any given volume of compressed air used requires double the volume of steam of the same pressure to compress and deliver it. We cannot see, either, how it would be possible to save any steam by using the steam pump and the water pressure. The cylinder must, at the last of each pressing stroke, be filled with water at the required pressure, and this could not possibly be applied without the use of something more than an equal volume of steam. Some system of levers or other mechanical devices could be employed which would show some saving of steam over the practice of filling the direct-acting cylinder for each compression; but we cannot suggest the arrangement without more knowledge of the actual press, and for satisfactory advice in any such case a practical engineer or designer should be consulted.

311. Q.—With what velocity should the air travel through the inlet and outlet valves of an air compressor, or what should be the ratio

of valve area to piston area, or what should be the area for short stroke and high rotative speed; also, what would be a safe working pressure for each valve?

A.—To secure the best results, the piston speed should not exceed 300 feet per minute, and for a small compressor it would be better to have it lower than that. Then for the inlet valves, allow one-twentieth of the area of the piston. As the outlet valves would pass a much smaller volume, according to the air pressure, their area may be less than that of the inlet valves. One-half the area of the inlet valves would be a liberal size for the common working pressures. The valve should be safe, if properly made, for any pressure required. If more than 75 or 80 pounds gage pressure is needed, two-stage compression is more economical and desirable.

312. Q.—Y. asks how to find the increase of temperature of a gas when compressed, as in the case of air compressed to a pressure of ten atmospheres.

A.—The ratio of absolute pressures being in this case 0.1, the ratio of absolute temperatures will be .5131, supposing the air to be compressed without loss or gain of heat. If the initial temperature is 60 degrees Fahr., the absolute temperature will be $60 + 461 = 521$, and the final absolute temperature will be $521 \div .5131 = 1{,}015$, and the final temperature by the Fahrenheit thermometer will be $1{,}015 - 461 = 554$ degrees. The formula from which the constant .5131 is derived is $\left(\frac{1}{R}\right)^{0.29}$, the $\frac{1}{R}$ being the ratio of the absolute pressures.

313. Q.—Where should the adiabatic expansion, or in this case the compression, curve start from; should it not be from the top instead of from the bottom, as in a steam expansion diagram?

A.—The curve would start from the point where the operation represented started. The expansion curve would start from the top and the compression curve from the bottom, although with the same pressures at each, and with dry air the two curves should be coincident.

314. Q.—Does the same formula apply to extreme measures, such as 2,000 pounds to the inch and above?

A.—It applies as far as experiment has gone. It is impracticable to compress to such high pressures by a single compres-

sion. Three or more stages of compression are employed, with a thorough cooling of the air between.

315. Q.—I am running a double-stroke air compressor—that is to say, two pumps, one on each end of a shaft. The pistons are 1 inch diameter and the stroke is 6 inches, running about 50 revolutions per minute and keeping up a constant air pressure of 50 pounds. The piston packing is a cup leather, with a steel washer behind nearly fitting the base, and a washer setting into the cup on the other side with a nut to tighten it up. The cylinder is water-jacketed, but the piston packing gives out and requires to be renewed about once a week. Would like to know some form of piston that would not cause so much trouble. The pump takes about one-quarter of a horse-power, and I would not want it to take much more than that.

A.—The leather probably burns out by the heat of the air when compressed. The water jacket, while it cools the barrel, cannot have much effect in protecting the piston packing. Metallic packing should be used. Any packing which would be suitable for a steam piston would be preferable to leather. Assuming the bore to be reasonably true, then a solid piston fitting as perfectly as possible, with a single iron ring sprung into a groove, or two such rings, should give good results. If the pistons are single-acting there should be no difficulty about oiling the cylinder, which should be done occasionally by some means. The pump probably now uses nearer a half than a quarter of a horse-power, and the metallic piston should not increase the power required.

316. Q.—Is there any leakage through the pores of metal pipes containing air under pressure of 100 to 150 pounds?

A.—Unless the pipes are defective—no. The reservoirs used in connection with the dynamite gun, and the compressed-air system of street cars carry pressures of 2,000 pounds and upward, and they hold this pressure for days, and even weeks, at a time with no material loss.

317. Q.—We have a pair of hoisting engines driven by compressed air. The cylinders are 15 inches diameter and 36 inches stroke, and the piston speed is about 200 feet per minute. The air at 60 pounds gage pressure is cut off at quarter-stroke. The unbalanced load raised is 2,800 pounds at a speed of about 400 feet

per minute. When the engines are running, a vacuum begins to be formed in the cylinder almost immediately after cutting off, certainly before half-stroke, and increasing to the end of the stroke. Why is this peculiar action produced? As the vacuum must mean "load" to the engine, what is the simplest means of negativing it?

A.—The engines are too large for the work. The air should not be cut off at quarter-stroke for any air pressure below 100 pounds gage. With 60 pounds air cut off at quarter-stroke the pressure will fall to atmosphere at three-quarter stroke, and, as in this case, this gives too much power, the air is also probably wire drawn by throttling, the initial pressure is not maintained to the point of cut-off, and atmospheric pressure may therefore be reached considerably before the three-quarter stroke, with, of course, increasing vacuum to the end. The horse-power required for the load is $(2{,}800 \times 400) \div 33{,}000 = 34$. The horse-power of the engines at the figures given, the mean effective pressure being 23.6 pounds, is: $15^2 \times .7854 \times 23.6 \times 200 \times 2 \div 33{,}000 = 50.5$. The difference is evidently more than should be required to overcome all friction, so that throttling must have been resorted to. The remedy would be to change the gearing, thereby slowing the engine relatively to the speed of the load. More accurate data all through should be secured before determining the speed ratio that would be most desirable.

318. Q.—What would be the loss by friction in a small air engine with cylinder 1 inch diameter by 4 inches stroke?

A.—We understand this to mean an engine or motor driven by compressed air. The friction should be no more, and on account of better lubrication should be less, than if the same engine was driven by steam.

319. Q.—How many strokes would an air pump or compressor with a cylinder of the above dimensions be required to make to get 200 pounds gage pressure in a tank of 1,000 cubic inches capacity?

A.—Two hundred pounds gage pressure, or 214.7 pounds absolute pressure, equals 14.6 atmospheres. $214.7 \div 14.7 = 14.6$. Then $1{,}000 \times 14.6 = 14{,}600$ cubic inches, the volume of free air required to be compressed to fill the tank with air at 200 pounds pressure; but as the tank would contain air at a pressure of one atmosphere when the compression was begun, the actual volume

of free air to be pumped into the tank would be 14,600 — 1,000 = 13,600 cubic inches. The capacity of one single stroke of the pump would be $1^2 \times .7854 \times 4 = 3.1416$ cubic inches, and $13{,}600 \div 3.1416 = 4{,}329$, the number of single strokes of the pump theoretically required. From 10 to 25 per cent. should be added to this to make up for clearance and leakage.

320. Q.—What is the rule for finding the atmospheric pressures at different elevations? I wish to ascertain how high I can raise water with a pump at elevations from 5,000 to 12,000 feet.

A.—At the sea level the pressure of the air is 14.7 pounds per square inch; at ¼ mile above sea level it is 14.02 pounds; at ½ mile, 13.33; at ¾ mile, 12.66; at 1 mile, 12.02; at 1¼ miles, 11.42; at 1½ miles, 10.88, and at 2 miles, 9.80 pounds per square inch. For a rough approximation we may assume that the pressure decreases ½ pound per square inch for every 1,000 feet of ascent. The weight of water also decreases, but the decrease is so slight that for practical purposes we may assume the weight of water to remain the same at all elevations at which a pump can be placed. For finding the hight through which water can be raised, divide the air pressure per square inch by the weight of a column of water 1 foot high and 1 inch square, which is usually taken at .434 pound. Hence, if the hight through which a pump can raise water at an elevation of 1½ miles is to be ascertained, we divide 10.88 by .434 and obtain $\frac{10.88}{.434} = 25.07$ ft. Allowance must be made for an imperfect vacuum in the pump, leaks, etc., which may reduce the hight to 20 or 22 feet.

321. Q.—Would it be safe to carry 100 pounds air pressure in a 30-gallon galvanized house boiler tested to 150 pounds water pressure?

A.—The risk would not be great, although the factor of safety would be small. We would certainly want to see the 150 pounds water pressure applied, or to have some better assurance of its actual application than the customary stenciled statement which those tanks carry.

322. Q.—If the boiler with the 100 pounds pressure of compressed air should explode in a frame building, 18x24, with 10-foot ceiling and one floor, would it knock the "daylights" out of the building and kill the engineer—that is, would the bursting be necessarily disastrous?

A.—The force of the explosion would not be nearly as great as that of a steam boiler of the same capacity and pressure. It would not "wreck" the building, nor do very serious damage; still, when the explosion occurred, we would prefer to be somewhere else.

323. Q.—What would be the explosive force of 1 cubic foot of air at 2,400 pounds pressure per square inch, supposing the steel cylinder in which the air is contained were to give way?

A.—This would be a case of purely adiabatic expansion. The ratio of initial to final, or atmospheric, pressure would be $(2{,}400 + 15) \div 15 = 161$; or reciprocally, $1 \div 161 = .00621$. For this ratio of absolute pressures the ratio of initial to final volumes would be about .025, or the final volume to the initial volume would be about 40 to 1. Then, for this ratio of volumes the ratio of the mean effective pressure to the initial absolute pressure would be .0488, and the mean effective pressure during the period of expansion in a cylinder of constant area would be $2{,}415 \times .0488 = 117.85$, or, deducting the atmospheric pressure, $117.85 - 15 = 112.85$. Supposing the air to be in a cylinder having an area of 1 square foot, or 144 square inches, and held by a piston within 1 foot of the length of the cylinder, thus securing the volume and pressure assumed above; then to allow the 1 cubic foot of air to expand to 40 cubic feet the piston must move 39 feet, and it would be driven that 39 feet with the mean effective pressure given above—112.85 pounds. The power developed in the operation would be $144 \times 112.85 \times 39 = 633{,}765$ foot-pounds. The power of gunpowder is usually assumed at 250,000 foot-pounds per pound of powder, so that the power here developed would be about equal to $633{,}765 \div 250{,}000 = 2.5$ pounds of gunpowder. In the explosion of an air tank of the above capacity, and with the air at the assumed pressure, the power as above approximately computed would, of course, be developed; but the actual practical results are not, after all, comparable with those resulting from gunpowder explosions. Although it is not easy to compute the time consumed in occurrences of this character, it is certain that the action of the gunpowder is much the quicker, and therefore more destructive, if the powder is confined. As a matter of fact, when the Mannesman tube tanks, which are now generally used for gases at high

pressure, explode there is no flying of pieces, but simply a rupture of the side of the tube, and no other damage results except to bodies actually in contact with the tank or in close proximity.

324. Q.—A asks for an estimate of the necessary thickness of material in a steel tank to hold air at 2,000 pounds per equare inch; also at 4,000 pounds; the dimensions of the first, 30x30x15 inches, and of the other, 30x20x12 inches. Space being at premium, and weight also a factor, would tanks or tubes be best?

A.—The dimensions given indicate that the "tanks" are to be rectangular. As it would be practically impossible to use such tanks for the purpose of high-pressure air storage, it would be useless to attempt any computation. Mannesman tubes of steel seem to be the best known means of carrying compressed air. Tubes 8 inches diameter and 5-16 inch are very commonly used. The weight is about 100 pounds for each cubic foot of capacity.

325. Q.—If this air was reduced to the proper pressure and used to run a small compound engine (efficiency 100 per cent.), what would be the horse-power developed per hour?

A.—We know nothing about efficiencies of 100 per cent., especially in this line, so that may as well be disregarded. If the tank full of air at 2,000 pounds pressure is at normal temperature, say 60 degrees, and if the air as it expands before use is allowed to come to this normal temperature, then 1 cubic foot of air at 2,000 pounds will be about 17.5 cubic feet at 100 pounds, and if this is so used that it will expand adiabatically to atmospheric pressure before release, the mean effective working pressure will be 44 pounds. The terminal volume will be 70 cubic feet. If the air were used in a single long cylinder of 1 square foot (144 square inches) area, the work done would be $144 \times 44 \times 70 = 443{,}520$ foot-pounds, and if the work were done in one minute it would represent $443{,}520 \div 33{,}000 = 13.42$ horse-power; if the work were done in an hour, then the horse-power would be $13.42 \div 60 = .223$. Heating the air before use and at an intermediate stage, if a compound engine were used, would increase this result at least 50 per cent. at slight fuel cost.

326. Q.—I have a 12x14-inch straight-line air compressor running two 3¼-inch rock drills. At times the steam drops as low as 50 pounds, and then the compressor fails to supply air enough. Is the compressor large enough for the work?

A.—If the compressor will keep up the air pressure when the steam pressure keeps up, then the compressor is large enough and the trouble is at the boiler. If the air supply falls when the steam pressure falls it is only because the speed of the compression also falls.

327. Q.—If the steam cylinder was increased to 13 or 14 inches diameter would it remedy the matter?

A.—It would not. It would not do the same work with any less steam. If the air cylinder were increased an inch in diameter the air capacity would be proportionately increased, and the steam cylinder would still have power enough to drive it. The working air pressure for the drills should be kept up to 75 or 80 pounds, and the steam pressure should never be below that.

328. Q.—What rule is there for determining the number of rock drills of a given diameter a 12-inch steam by 12-inch air by 14-inch stroke compressor should run with a given steam pressure?

A.—It can only be said in a general way that a 3-inch rock drill will require about 100 cubic feet of free air per minute, and a 3½-inch drill about 150 cubic feet. The actual free-air capacity of compressors is always less than the theoretical capacity given in the catalogs. As a matter of fact, a 12-inch compressor is not quite large enough to keep two 3½-inch drills running continuously. It is usually assumed that one or the other of the drills will be stopped a considerable portion of the time. The question of steam pressure scarcely applies to the case. There must be steam enough to keep the compressor running up to speed. Any higher pressure would not increase the volume of air delivered, and the speed of the compressor would drop off rapidly when the steam went down.

329. Q.—What is the formula for calculating the quantity of air which at any constant pressure will escape through an opening of any known area?

A.—The following formula gives the theoretical discharge:

$$V = A \times 37.8 \sqrt{P \times P}$$

V being the volume of free air discharged in cubic feet per minute, A the area of the orifice, P the absolute pressure, and P' the gage pressure. The actual discharge will be less than indicated by this formula, and may not be more than from 50 to 70

per cent. of it. Applying the formula to the case above, we have:

$$V = .003 \times 37.8 \sqrt{75 \times 60} = 7.50$$

and 50 per cent. of this is 3.8.

330. Q.—Theoretically, if compressed air is re-expanded in a cylinder it loses the same amount of heat that was produced by its compression. For example, if free air with an initial temperature of 60 degrees is compressed to 50 pounds gage its temperature is 339 degrees, the increment being 279 degrees; maintaining it at 50 pounds, and if it is then admitted to a cylinder and re-expanded to atmospheric pressure, the temperature will fall 279 degrees, and the volume will be as the absolute temperature. Is this correct?

A.—If the air is expanded from 50 pounds gage to atmospheric pressure, the ratio of pressures will be $\frac{15}{50 + 15} = .23+$, and for this ratio of pressures the ratio of absolute temperatures will be .65. The final temperature, then, will be $(60 + 461) \times .65 = 338 - 461 = -123$, and the decrease in temperature will be $521 - 338 = 183$ degrees.

331. Q.—If, however, before the air is used, it is heated to 400 degrees, and is then used as above, will the temperature then fall 279 degrees, the original increment during compression, or will it fall more?

A.—In this case the ratio of pressures will be, as before, .23+, and the ratio of absolute temperature will also be the same, .65. The final temperature, then, will be $(400 + 46) \times .65 = 559 - 461 = 98$ degrees, and the decrease in temperature will be $861 - 559 = 302$ degrees.

332. Q.—What will be the diameter of a cylinder 18 inches long to hold enough compressed air at 60 pounds gage pressure to run a nozzle with 1-64-inch outlet 20 minutes, and still have a pressure of 5 pounds?

A.—We assume that a pressure reducer is employed, and that the nozzle will constantly discharge the air under a pressure of 5 pounds, so that a uniform flow of air will be maintained. Air at 60 pounds gage pressure, or 75 pounds absolute, or 5 atmospheres, will occupy one-fifth of the space occupied by the same air at a pressure of 1 atmosphere, free air, so that the capacity of the receiver will be one-fifth of that required for the total

volume of free air employed. By experiment it has been ascertained that a 1-64-inch nozzle with a pressure of 5 pounds will discharge .07 cubic feet of free air per minute; and for the 20 minutes, therefore, the discharge will be $.07 \times 20 = 1.4$ cubic feet, or, say, 1.5 cubic feet of free air. When the pressure in the cylinder has fallen from 60 pounds to 5 pounds it will still contain $\frac{20}{75}$ or $\frac{4}{15}$ of the original charge; and as this amount used has been $\frac{55}{75}$, or $\frac{11}{15}$ of the original charge, and as that, as previously ascertained, is 1.5 cubic feet of free air, we add $1.5 \times \frac{4}{11} = .54$ to this, making together 2.04 cubic feet, or, say, 2 cubic feet; and as one-fifth of this volume, .4 cubic feet, or 691 cubic inches, is the capacity of the cylinder required, with 18 inches for the length of it, we assume x for the diameter, and its value is readily ascertained, as follows:

$$x^2 \times .7854 \times 18 = 691,$$

and $x = 7$ inches, the diameter required, very nearly. It may be well to remember that 1-64 inch is a very small hole, and, in practice, a slight variation in the size of it might apparently belie these figures.

333. Q.—What should be the size and power of an air compressor to fill a reservoir 16 inches diameter and 2 feet long, pressure in reservoir to be 50 pounds at the end of a half-hour?

A.—The capacity of the tank is $12^2 \times .7854 \times 24 = 4{,}825.5$ cubic inches $= 2.79$ cubic feet. A pressure of 50 pounds is equal to, say, 4⅓ atmospheres; $(50 + 15) \div 15 = 4\frac{1}{3}$; and as the reservoir at the beginning will contain air at a pressure of 1 atmosphere, there will remain only 3⅓ atmospheres to be pumped in. Then, $2.79 \times 3\frac{1}{3} = 9.3$ cubic feet of free air to be pumped in 30 minutes. This would be at the rate of .31 cubic foot, or 535.68 cubic inches, per minute. If the pump made 100 strokes per minute, the required free-air capacity would then be 5.36 cubic inches per stroke; and assuming the pump to be single-acting, this, with a liberal addition for contingencies, should be the piston displacement. A plunger pump 1¼ inches diameter and 6 inches stroke would give $1.25^2 \times .7854 \times 6 = 7.32$ cubic inches, and this should be sufficient. The power re-

quired for the pump would be very light at first, and would increase with the pressure in the reservoir. The final rate of power required would be $1.25^2 \times .7854 \times 27 \times \frac{1}{2} \times 100 \div 33{,}000 = .048$ horse-power. A pump could be made that would enable a man to fill the above reservoir in 10 minutes or less, but we have answered the question as it was asked.

334. Q.—Would it have any effect upon the capacity of an air cylinder if the piston, instead of working very close at each end, should have a clearance of, say, 1 inch on a cylinder 14 inches diameter, and, if so, what would be the effect? Say that I have an air compressor with 16-inch steam cylinder and 14-inch air cylinder, 18-inch stroke, and carry an air pressure of 80 pounds, all other things remaining the same, will increasing the clearance have any material effect?

A.—Increasing the clearance would certainly have an effect, and the effect would be bad. In an air compressor it is always desirable to have as little clearance as possible in the compressing cylinder at the end of the stroke, because after compressing the air the work is not completed unless the air is actually delivered into the receiver. What is not delivered merely re-expands, and so far as that portion of the contents is concerned, the work of compression must all be done over again. With 18-inch stroke and 1-inch clearance when compressing to 80 pounds gage pressure, or, say, 6⅓ atmospheres, the air upon re-expanding down to 1 atmosphere again, on the return stroke of the piston, would only reach atmospheric pressure after the piston had traveled about 6 inches, or one-third of its stroke; so that one-third of the length of the stroke would be filled with this old air, and only two-thirds of the stroke would be filled with new air taken in from the outside. The 1-inch clearance would practically take away about one-third of the compressing capacity of the cylinder. The loss in power would not correspond with this loss in capacity, because the air in expanding would re-exert the force which had been employed in compressing it, and to that extent would be helping to drive the machine.

335. Q.—What difference, if any, should be made in the design or construction of a small engine, say 10 horse-power, to run by compressed air instead of by steam, at the same pressure?

A.—There would be practically no difference. We have

known common steam engines run quite satisfactorily by compressed air, and hoisting engines are used in mining plants that are run by either compressed air or by steam indifferently, as may be most convenient. If the air is to be used economically the engine should, of course, have a cut-off, and for the same pressure the theoretical cut-off for air should be later than for steam. An automatic cut-off would, however, take care of itself in either case. At 80 pounds gage pressure steam cut-off at .2 stroke would give very nearly the same terminal pressure, a little above 1 atmosphere, as air cut off at .3 stroke, although the mean effective pressure in this case would be higher for the air than for the steam. If the engine is to be run constantly a reheater should be employed for the air. It would increase the ultimate efficiency of the air more than a condenser does for steam, and it would also avert all danger of choking the exhaust by frost.

336. Q.—I wish to discharge a large number of jets of compressed air through ⅛-inch pipes at a pressure of about 4 atmospheres. Would it be best to use a non-compound compressor, and run the air to the pipes through a reducing valve; that is, would not the latter use less steam for compressing?

A.—The higher the pressure to which any given volume of air is compressed the greater will be the power required to compress it. The saving of power effected by two-stage compression, with efficient cooling of the air between the stages, is not available in compressing air to only 4 atmospheres. We would use a single-stage compressor with a well-jacketed cylinder. If the air was to be carried a long distance, the saving in pipes might warrant the carrying a higher pressure and the use of a two-stage compressor, as suggested; otherwise the single compression would be simplest, cheapest and best.

337. Q.—If I have an iron bottle holding 1 cubic foot of air at 1,500 pounds gage pressure, what horse-power can I get if I allow this air to expand to atmospheric pressure in one minute, the temperature being kept constant; and what would be the mean air pressure?

A.—It would be impossible practically to fulfill the above conditions, but we can give the theoretical result. Calling 1 atmosphere 15 pounds, a gage pressure of 1,500 pounds would be

an absolute pressure of 101 atmospheres. For convenience we assume that we have 100 atmospheres, and that the air is contained in a cubical vessel measuring 1 foot each way. If the vessel is elongated to 100 feet total length, and one side of the original cube is transformed into an air-tight piston without friction, then if this piston is driven by the expanding air 99 feet, the original temperature being maintained all the way, the mean air pressure for the stroke will be 54.75 pounds. The work done will then be 12 inches $\times$ 12 inches $\times$ 54.75 pounds $\times$ 99 feet = 780,516 foot-pounds, and 780,516 $\div$ 33,000 = 23.65 horse-power.

338. Q.—If I took this same air and expanded it to 60 pounds, gage, through a reducing valve, keeping the temperature constant, and then used this air in 1 minute in an engine cutting off at one-third stroke, what horse-power would I get?

A.—We would have, to begin with, 20 cubic feet of air, or 5 atmospheres : 100 atmospheres : : 1 cubic foot : 20 cubic feet. Now, if we had a regular engine or motor, with cylinder 6 inches diameter and 1 foot stroke at 153 revolutions per minute, 306 feet piston speed, it would use, saying nothing about clearance or leakage, almost exactly 20 cubic feet per minute when cutting off, as proposed, at one-third stroke: $6^2 \times .7854 \times (306 \div 3) \div 144 = 20.02$ cubic feet. The mean effective pressure for air at 60 pounds gage pressure, cut off at one-third stroke and expanding adiabatically, is 32.13 pounds. The power developed then will be: $6^2 \times .7854 \times 32.13 \times 306 \div 33{,}000 = 8.42$ horse-power. From this should be deducted, say, 10 per cent. for the friction of the engine: 8.42 — .842 = 7.578, and from this again 25 per cent. for clearance and leakage: 7.578 — 1.894 = 5.68 horse-power, which is about what would be practically realized under the conditions given.

339. Q.—Are the mean air pressures given in Table VI, Richards' "Compressed Air," for adiabatic or isothermal expansion?

A.—For adiabatic expansion. We learn this by looking at the back. Why could not the questioner do so?

340. Q.—Is not the atmosphere the same weight at any hight that it is at the sea level?

A.—The atmosphere is held to the earth by gravity, as is any other substance, and the pressure at sea level is due to the total

weight of air above. The air, being compressible, is denser at the lower levels, since at elevated positions the column above weighs less by the weight of the column between the given position and the sea level below. These matters are treated in detail in works on physics, which you will do well to consult.

341. Q.—What would be the smallest safe size to turn down a piston rod for a single-action ammonia compressor, 11 inches diameter by 27 inches stroke, 200 pounds condensing pressure? The original diameter of the rod is 2 7-16 inches. Please give formula, if convenient.

A.—We assume that this rod is made of steel, and the authoritative formula giving the smallest size for a piston rod for an engine would be that given by Unwin, which is as follows: $d = b\ D, \sqrt{p}$. In which $b = .0144$ for steel. This would give for the size of this rod 2.16 inches; but the fact that the pump is single acting, and that the rod is subjected to compressive stress, only, instead of alternate compressive and tensile stresses, as in an engine piston rod, would probably make it safe to reduce the rod to 2 inches, though in doing this it should be remembered that there is a strong probability that the rod was originally made about the size that the makers of the machine had found it advisable to make it, and any material reduction of diameter ought not to be made except as a necessity.

342. Q.—I have an air compressor of the following dimensions and working under the following conditions: Cylinders (steam and air alike), 12x12 inches; cut-off, ¾ stroke; steam pressure, 95; air pressure, 80; revolutions, 120 per minute; and desire to know (1) What is the horse-power of the steam cylinder? (2) How many pounds of water per hour would be obtained if the exhaust were condensed by a surface condenser?

A.—The horse-power of the steam cylinder can only be determined from the work required to compress the air, and not from the steam pressure and point of cut-off. The throttle valve will be set by hand, or by the regulator, if the compressor has one, to admit enough steam to drive the machine at the desired speed. At the sea level the mean effective pressure in the air cylinder, when compressing to 80 pounds, would be about 36.6 pounds, and the horse-power of that cylinder would be

$$\frac{36.6 \times 113 \times 380}{33{,}000} = 37.6$$

The friction of a machine of this kind and size would probably be about 10 per cent. of the load, or in other words, the horse-power of the steam cylinder would be about 10 per cent. greater than the above, or, say, 41 horse-power. (2) If the engine is in good condition, probably about 2,000.

343. Q.—Our air compressor is a mile from the mine; there is a 4-inch pipe to a receiver in the mine, and then a 2-inch pipe to the drills; is the latter pipe large enough to supply five drills?

A.—Assuming the drills to be 3 inches, the size most commonly used, allow 100 cubic feet of free air per minute for each drill, or, say, 400 cubic feet for the five drills, as they do not work constantly, and usually not all at once. If the air is used at 6 atmospheres, or 75 pounds gage, the volume transmitted will be only one-sixth of this, or, say, 67 cubic feet per minute. The flow through the pipe should not exceed 30 feet per second, or 1,800 feet per minute. The area of a 2-inch pipe is 3.14 square inches, or .0218 square foot; then $1{,}800 \times .0218 = 39.24$ cubic feet per minute, or less than two-thirds of the required capacity. Many mines are piped as inadequately as this, but it does not pay if the use of the air is to be more than temporary.

344. Q.—What is the best piston ring packing to use for air hoists, supposing the pressure is 70 pounds and the diameter of the cylinder 5 inches, and the pressure alternately on each side of the piston? The packing must be absolutely tight, so that when the load is raised and the air shut off the load will not fall.

A.—The best packing which we know of, and that is also commonly used, is a leather cup on the face of the piston, with lips that are set out to the cylinder surface by the air pressure. If, as stated, the pressure is to be applied to both sides of the piston, there should be a cup leather on each side, and there should be some projection or stop to prevent mutilation of the lip when the piston reached either end of the cylinder. We have never heard of any air hoist piston packing being made "absolutely" tight, although in most cases when the air supply is shut off the descent of the load is quite slow. The air seems to ooze through the leather even if the lip is in perfect contact with the cylinder. The leakage is probably not greater in pneumatic than in hydraulic service.

345. Q.—I have an air compressor, operated by a gasoline engine, in an

Arizona mine, where water is very scarce, and where it is necessary to use the water over and over again in the jackets of engine and air cylinders. The air drills run but part of the time. Would it be possible to utilize the compressed air from the plant for cooling the water, and, if so, what device would be suitable for this purpose? The water is stored in wooden tanks.

A.—It would not be advisable to attempt to cool the water by an air jet, as it would cost more than it would be worth. We would advise you to investigate the water-cooling towers which are used to cool the condensing water from the steam engines, so that it may be used over and over. We can see no reason why this process should not be equally applicable to your case. We may add that we have known compressors, in cases of restricted water supply, to be run without water in the jackets. The air cylinder gets pretty hot, but no harm comes of it. For your gasoline engine you of course require water.

346. Q.—I have an air compressor for experimental purposes, compressing to 150 pounds gage pressure at a single compression; can you tell me how to compute the final temperature of the air?

A.—The formula $\left(\frac{1}{R}\right)^{0.29}$ will give the ratio of the initial to the final absolute temperature, R being the ratio of absolute pressures, or R is $(150 + 14.7) \div 14.7 = 11.2$, and $\frac{1}{R}$ is $14.7 \div (150 + 14.7) = .0892$. The logarithm of this will be $\bar{2}.950365$, and multiplying this by 0.29, we have $\bar{1}.695606$, which, by the table, is the logarithm of .496, the required ratio of absolute temperatures. This operation of multiplying a mixed logarithm by a decimal may not be familiar to some of our readers. Multiplying first the mantissa, or decimal part, of the logarithm, we have $.950365 \times .29 = .275606$, and multiplying the negative characteristic we have $-2 \times .29 = -.58$. We then add $-.42$ to this, $-.58 + -.42 = -1.$, and also add $+ .42$ to the mantissa, $.275606 + .42 = .695606$, and the complete logarithm is then, as above, $\bar{1}.695606$. If we assume the initial temperature of the air to be 60° Fahr., the absolute temperature will be $60 + 461 = 521$, then $521 \div .496$ (as obtained above) $= 1{,}050$, and then $1{,}050 - 461 = 589°$, the final temperature by Fahrenheit thermometer. It seems to be our duty to warn our correspondent that the prac-

tice of compressing air to such a pressure at a single compression is a dangerous one if mineral oil is used for lubrication.

347. Q.—If a tank is filled with compressed air to about 100 pounds per square inch, is it more buoyant than one which is not filled with compressed air?

A.—It is more buoyant than one not filled with compressed air, provided the one not filled with compressed air is filled with something heavier than compressed air at 100 pounds per square inch pressure. It is less buoyant than one filled with air at ordinary atmospheric pressure, and is still less buoyant than one from which the air has been entirely exhausted.

348. Q.—How long does it take one gallon of liquid air to evaporate when it is properly protected by felt or other heat insulating material?

A.—We are reliably informed that a single gallon of liquid air may be kept for more than twenty-four hours, while in quantities of ten gallons it will take three or four days to evaporate it all.

349. Q.—What is the formula for the velocity and discharge of air through orifices?

A.—The theoretical formula for the quantity discharged is:

$$V = A \times 37.8 \sqrt{P \times P^1},$$

in which

V = cubic feet of free air discharged per minute,

A = area of orifice in square inches,

P = absolute pressure in receiver in pounds per square inch,

P^1 = difference in pressure within and without the receiver in pounds per square inch.

We know of no experiments to determine the value of the coefficient of discharge for high pressures, but for pressures of 60 to 70 pounds some rough experiments indicate a coefficient of about .7.

350. Q.—I have a 32-gallon tank filled with water, on which I require a pressure of about 5 pounds to the inch while being drawn off. To what pressure must I compress air in a tube 2 inches diameter and 6 inches long to supply the above tank?

A.—As 1 gallon is 231 cubic inches, the cubic capacity of the tank is $231 \times 32 = 7{,}392$ cubic inches. The capacity of the proposed compressed air reservoir is $2^2 \times .7854 \times 6 = 18.85$ cubic

inches. When the last of the water is expelled from the tank there should be a pressure of 5 pounds of air in the reservoir. Then, saying nothing about the contents of any connecting piping that may be required, the volume of the air will be 7,392 + 18.85 = 7,410.85 cubic inches at 5 pounds gage pressure, or 5 + 15 = 20 pounds absolute pressure. As all this air must at the beginning be contained in the air reservoir, the absolute pressure required in it will be inversely as the volumes, or 18.85 : 7,410.85 :: 20 : 7,863 pounds absolute pressure, or 7,863 — 15 = 7,848 pounds gage pressure. The scheme is, of course, impracticable on account of the small capacity of the proposed air reservoir. With an air receiver having the same capacity as the water tank, the case would be different. Then, saying again nothing about pipes or leakage, the initial pressure required would be double that of the terminal pressure, or 20 × 2 = 40; the gage pressure, of course, being 40 — 15 = 25.

351. Q.—If I were to place 200 feet of 1-inch steel tubing in water, the temperature of which is 371 degrees, what effect would a current of air, at average temperature, pumped through the tubing have on the water in the sense of lowering its temperature; also, how hot would the air be on leaving the tubing? The air is to be used for drying, and it is important that it should be very hot. Would it be better to use a cylinder in which to store a quantity of air before allowing it to circulate through the pipes, or to pump the air through the pipes first and store the heated air in the cylinder or reservoir ready for use?

A.—The temperature of 371 degrees for the water corresponds to a steam gage pressure of 161 pounds, and the total heat units in each pound of the water above 32 degrees, 343.9. To determine the cooling effect upon the water it is necessary to assume some known volume or weight of water as here subject to the cooling action of the air. Say that the volume of hot water is 10 cubic feet; then, as the weight per cubic foot for water at 371 degrees is 55 pounds, the total weight of the water is 550 pounds, and to raise or lower the temperature of the water 1 degree 550 units of heat must be transmitted to it or abstracted from it. We cannot say, and there is no means of computing the temperature to which the air would be raised, but from experience it may be assumed that the temperature would

be raised to at least 350 degrees. With a pressure of 1 pound driving the air through the pipe, the rate of flow would be 12.72 feet per second, or, say, 750 per minute (Richards' "Compressed Air"). As 167 feet of 1-inch pipe contains 1 cubic foot, the volume of air per minute would be 200 ÷ 167 = 1.2 cubic feet, and the weight of the air at, say, 60 degrees (the weight of 1 cubic foot at that temperature being .0764 pound) would be 1.2 × .0764 = .0917 pound per minute. The specific heat of air, or the heat required to raise the temperature of 1 pound of air 1 degree, being .2377 heat unit, and the temperature being assumed to be raised from 60 degrees to 350 degrees, or 290 degrees, the heat units to be taken from the water per minute will be .0917 × .2377 × 290 = 6.32 heat units. As it would require the abstraction of 550 units of heat to lower the temperature of the hot water 1 degree, the actual lowering of temperature due to the passage and heating of the air would therefore be 6.32 ÷ 550 = .0115 degrees, or a little over one-ninth of 1 degree per minute. The air when heated should be used at once, and should be transmitted as quickly and directly as possible. It will be found impracticable to store heated air.

352. Q.—Does air under high pressure lose any of its elastic properties?

A.—Never, until it liquefies, and this does not occur except at pressures above 2,000 pounds, in combination with a temperature of more than 200 degrees below zero.

353. Q.—I have an air compressor, with steam cylinder 6x8 inches and air cylinder 10x8 inches, running at 300 feet piston speed. The steam pressure is 90 pounds, gage, and with this a pressure of 60 pounds is maintained in the air receiver. With the great difference in the areas of the steam and the air cylinders, how can it be possible to maintain so high an air pressure?

A.—The area of the steam piston is 28.27 square inches, and, as the steam may be assumed to have followed full stroke, we may assign it a mean effective pressure for the stroke of, say, 85 pounds. The total mean effective pressure on the steam piston, then, is 28.57 × 85 = 2,402 pounds. The area of the air compressing piston is 78.54 square inches. The theoretical mean effective pressure for adiabatically compressing and delivering the entire contents of the air cylinder at a pressure of 60 pounds, gage, the compressor working at sea level, is 30.75 pounds. In

practice the mean effective pressure is somewhat lower than this, for the reason that all the air is not expelled from the cyilnder on account of the clearance, and that also the air loses some of its heat, if only a little, during the compression. We may, therefore, call the mean effective pressure in this case 30 pounds. The total mean effective pressure upon the air piston will then be $78.54 \times 30 = 2{,}356$ pounds. As the pressure upon the steam piston is, as found above, 2,402 pounds, or only 1½ per cent. greater, it is evident that the preponderance of the steam pressure is not sufficient. In the best running compressors the steam pressure should have an excess over the air pressure of 10 or 15 per cent. In the case of the air compressor of our correspondent there is another operative condition which we have not yet considered, and which has an important bearing upon the result. It is to be remembered that Anaconda, Mon., is at a considerable elevation above the sea level. It is not necessary for us here to know its precise altitude. At an altitude of 10,000 feet above the sea the theoretical mean effective pressure for adiabatic compression to 60 pounds gage is only 26.21 pounds, instead of 30.75 as at sea level. This is not because the compression is done with a less expenditure of power, but because less air is compressed and actually delivered per stroke. Making a little deduction for the practical conditions of compression, as in the case of compression at sea level, and calling the mean effective pressure 26 pounds, the total mean effective pressure on the air piston will be $78.54 \times 26 = 2{,}042$ pounds. As the mean effective pressure on the steam piston, 2,402 pounds, is more than 17 per cent. greater than this, the ability of the compressor to do the work is accounted for. The elevation easily accounts for the running that would be impossible at the sea level.

354. Q.—In a 6-inch wrought-iron pipe line, with natural gas flowing through at velocities ranging from 275 to 515 feet per second, there are two pieces of ⅛-inch brass pipe inserted of an external diameter of ⅜ inch. One piece runs in 4½ inches from the inside wall of the 6-inch line, the other 2½ inches. In calculating the cubic feet of flow should allowance be made for their area; if so, how much?

A.—Short obstructions of this kind offer but slight resistance to the flow of gases. We have known diaphragms to be in-

serted in pipes to test the matter, and the results showed that the opening in the diaphragm must be surprisingly small to produce a sensible effect. We do not think that your small pipes would make a difference in the delivery sufficient to measure.

355. Q.—In an air compressor what are the correct ratios of areas of inlet and outlet valves to that of the air cylinder?

A.—There is no such thing as correct ratios in cases of this character. Valve areas on a compressor depend largely upon the style of valve employed; that is, whether the opening is one concentrated area, and also whether the valve is held open to get all this area throughout the stroke. Roughly speaking, about 5,000 feet per minute velocity for the air passing the valve gives good results, a slow-running machine, that is, one having low piston speed, hence requiring a smaller valve area than a high speed. In compressors using the "piston inlet" valve and having from 300 to 350 feet piston speed the inlet area is from 5 to 6 per cent., this area, however, being concentrated and positive for the whole length of the stroke. In this case the velocity of the air is 7,000 feet per minute, but good results are shown. On large compressors, where the steam cylinders are of the Corliss type, and the piston speeds are as high as 500 to 600 feet per minute, the inlet areas, with the same type of valve as before, range from 6½ to 7 per cent., and the discharge areas (poppet valves) from 10 to 12 per cent., giving about the same velocity in the air passages as with the slower machines. On machines having poppet valves all around probably 12 per cent. of area is necessary, as machines with but from 7 to 10 per cent. area have shown considerable vacuum on the inlet, the springs tending to hold the valves partially closed and reducing the practical area. About 10 per cent. area for both the inlet and the discharge valves should be sufficient for almost any good style of valves and for piston speeds not exceeding 400 feet per minute. The area of the discharge valves should not be less than that of the inlet valves, as, although the volume of air passing the discharge valves is, of course, much less than that passing the inlet valves, the time allowed for the passage is also proportionately less. While the inlet valves are open, or should be, during the whole of the intake stroke, the discharge valves can be open only for one-fourth or one-fifth, or other small portion, of the stroke, according to the pressure.

356. Q.—Is it necessary to circulate water around an air compressor cylinder to keep it cool when the air pressure does not exceed 70 pounds, gage?

A.—Taking in the air at 60 degrees, its final temperature when compressed adiabatically to 70 pounds is 405 degrees. The interior surfaces of the cylinder do not get as hot as this, but they get so hot that it is found very desirable to water-jacket or otherwise cool the cylinder. If not so cooled there is likely to be trouble with the lubrication of the working surfaces. The cooling of the cylinder also accomplishes a slight saving of power by keeping the volume of air in the cylinder a little less than it otherwise would be.

357. Q.—What provision is made to keep the air cylinder cool on Westinghouse air-brake pumps?

A.—The cylinders of these pumps are not water jacketed, but as the engines normally run at a considerable speed, the rush of air past the cylinders has a very appreciable cooling effect. The pumps also run only intermittently, and the cylinders therefore do not get nearly as hot as with constant running.

358. Q.—What is the construction of the sight feed lubricators used on air compressing engines?

A.—As we do not know what kind of lubricator is here referred to, we can give only a general answer. The lubricator is usually placed upon the middle of the cylinder, and as the piston makes its alternate strokes the pressure within the cylinder varies between atmospheric pressure, or a little below it, and a pressure of, say, 2 atmospheres (absolute), and advantage is taken of this constantly varying pressure. A small tube leads to the top of the lubricator chamber, with a little check valve to retain all that passes the tube. When the air pressure is the greatest a minute portion of air passes up the tube and is retained in the top of the oil reservoir, the air thus accumulated exerting a constant pressure upon the oil. The oil passes by a restricted or adjustable passage from the lower part of the oil reservoir to the cylinder, there being an excess of pressure above the oil for a portion of each stroke.

359. Q.—What kind of oil is best for air cylinders?

A.—An oil which will not leave a residuum in the cylinder and passages. Oil dealers should be consulted, as their exper-

ience has enabled them to select the oils most suitable.

360. Q.—What is the best speed to run an air compressor with cylinders 12 inches and 12 inches diameter by 12 inches stroke, compressing to 70 pounds gage?

A.—Generally speaking, the worst speed is a high speed. Compressors of the dimensions here given are often run as fast as 150 turns a minute, or at 300 feet per minute piston speed, but we would prefer and recommend 100 turns per minute, or 200 feet of piston travel.

361. Q.—How many volumes of free air must be compressed to obtain any given pressure?

A.—Divide the absolute pressure of the compressed air (or the gage pressure plus the pressure of the atmosphere, usually at sea level called 14.7 pounds) by the pressure of the atmosphere, and the result will be the number of volumes of free air required. Thus, to compress air to 75 pounds gage the number of volumes of free air required will be $(75 + 14.7) \div 14.7 = 6.1$ atmospheres. This assumes that the compressed air is at the same temperature as the free air. As to the effect of different barometric pressures and temperatures see Richards' "Compressed Air."

362. Q.—In a compressed air plant where it is advisable to cool the air, or, rather, allow it to cool, as much as possible before conveying it to the machines, is there any gain in using a receiver 3 feet diameter by 10 feet long, vertical instead of horizontal, the air being taken from the bottom in either case?

A.—It is better to have the receiver vertical, admitting the air at the top and taking it out about 2 feet from the bottom of the receiver. The air will not cool as rapidly in the receiver as it will in the pipes, and if it could traverse pipe enough to become thoroughly cooled before going into the receiver, then more water would be deposited in the receiver, or the air would be drier, and less likely to "freeze up" in working.

363. Q.—How is the quantity of compressed air required to operate the Pohle air-lift pump calculated, and how is the required air pressure determined?

A.—The Pohle air-lift pump consists essentially of a vertical pipe and of a smaller air pipe within it, both pipes open, or having openings in the lower end. The water to be raised stands nor-

mally at a considerable hight in both pipes. To start the pump in operation there must be sufficient air pressure to first drive the water down and out of the air pipe. The pressure of air required for this operation is the greatest ever required, and usually much greater than is required after the lifting of the water is in full operation. Having by sounding or other means, ascertained the submergence, or the vertical distance in feet from the standing level of the water in the pipe down to the open end of the air pipe, multiply this by .434, and this will give the theoretical gage pressure in pounds per square inch required to expel the water in the air pipe and to cause the air to begin to escape from the lower end of the pipe and to rise in the water pipe, carrying the water with it. To the pressure as thus computed should be added at least 10 per cent. to overcome the friction and get the column in motion. If the submergence in feet is simply divided by 2, the result gives the required gage air pressure with sufficient exactness. To ascertain the quantity of water per minute that will be raised by a given volume of *free* air, the following formula, from the columns of "Compressed Air," is used:

$$G = \frac{125\,A}{L}$$

where G is the gallons per minute, A the volume of *free* air in cubic feet per minute, and L the lift, or the hight to which the water is raised above the standing level in the pipe. The formula, of course, may be transformed as follows:

$$A = \frac{G\,L}{125}$$

$$G = \frac{125\,A}{G}$$

It is assumed throughout that the submergence is at least one and one-half times the lift. Thus, if the lift is 80 feet, which is as high as it is usually profitable to raise water by this device, then the submergence should be 120 feet. With this lift of 80 feet, then, and a compressor delivering 100 cubic feet of free air per minute at a gage pressure of 60 pounds, the quantity of water raised per minute would be:

$$G = \frac{125 \times 100}{80} = 156 \text{ gallons.}$$

The other important question in connection with this is as to

the size of the pipe required, and for this we find no fixed rule, and can only offer a suggestion, which, however, may not be far out of the way. In the above case a 1½-inch pipe would be sufficient for the transmission of 100 cubic feet of free air per minute when compressed, as here required, to 60 pounds gage pressure. Then if the water pipe was 3½ inches diameter, the available area of cross-section of water pipe, deducting the area of the air pipe, would be about 6 square inches. Then, $156 \div 6 = 26$, the number of gallons of water lifted per minute per square inch of available section of water pipe. For convenience this may be made 25 instead of 26. The conditions under which the air-lift pump is used vary so greatly that no very precise formulas seem to be applicable. The rapidity with which the water will continue to flow to the pipe and maintain the supply after pumping is begun is a very important factor in the case, and this can only be ascertained by experiment.

364. Q.—Will more force be required to move one smooth surface upon another when the pressure of the surrounding medium, say air, is 100 pounds per square inch than when it is at atmospheric pressure, or zero?

A.—If the surfaces fit each other, and are in intimate contact, increase of pressure will increase the force required to move them.

365. Q.—Can I get the same results by sounding an ordinary steam whistle with compressed air as I should by using steam, pressure, steam or air space, piping, etc., being equal in each case?

A.—The results, with the exception of the tone, will be the same in both cases; the quantity of air required may surprise you.

Electricity.

366. Q.—Does electricity go up or down a lightning rod?
A.—Down.

367. Q.—What feature of a dynamo constitutes it a constant potential machine?
A.—Shunt winding.

368. Q.—What feature of a dynamo constitutes it a constant current machine?
A.—Series winding.

369. Q.—What is the result of running a dynamo too slowly?
A.—Reduced voltage and, against the same resistance, reduced current.

370. Q.—What is the result of running a dynamo too fast?
A.—Increase of voltage and, if the resistance is unchanged, of current.

371. Q.—What is the result of operating a motor at too high a voltage?
A.—Increased speed.

372. Q.—What is the result of operating a motor at too low a voltage?
A.—Reduced speed.

373. Q.—Can a current be maintained at a very high voltage and of but a fraction of an ampere of volume?
A.—Certainly.

374. Q.—On a complete metallic circuit furnishing power to run various motors and lights, will a person receive a shock by touching one wire, assuming the circuit to be perfectly insulated at all other points?
A.—No.

375. Q.—Where should I place a circuit breaker to protect a generator?
A.—Near the generator.

376. Q.—Where on a branch circuit to protect several motors?
A.—They are usually placed near the division point.

377. Q.—When two or more dynamos are run together, why must the voltage of the machines be equal without regard to the current of each?

A.—If dynamos are connected in multiple the voltage must be equal, or otherwise the stronger would prevail over the weaker and force the current through it backwards. If they are connected in series this no longer holds, as the voltages of the two machines are added together and the current through each is the same, as they form part of the same circuit.

378. Q.—What is the proper number of 16 candle-power incandescent lamps to illuminate a given amount of space?

A.—A good general rule is to allow one 16 candle-power lamp for each 100 square feet of floor space when the lamps are 7 to 8 feet above the floor and fairly well distributed, which will give fair, though not brilliant, illumination. If the lamps are grouped in a few chandeliers, or are at a high elevation, more should be used. It is quite obvious that good judgment must be a large factor in work of this kind.

379. Q.—What are the elements mostly used in closed circuit batteries?

A.—Copper and zinc.

380. Q.—How many volts can be obtained from one battery?

A.—Different batteries vary between about one and two volts per cell. A good commercial battery should give nearly or quite one and a half volts per cell.

381. Q.—Can you give me any calculations for computing a battery?

A.—Let N = total number of cells,

n = number of cells in a row of series,

e = E. M. F. of one cell,

r = resistance of one cell,

l = external resistance.

Then $\frac{N}{n}$ = number of cells in a row in multiple, and

$$\text{current} = \frac{n\,e}{\frac{n^2\,r}{N} + l}$$

382. Q.—Is it necessary in making a horseshoe magnet to harden it all over or only at the ends? Would it be better to polish it part way up from the ends or only the faces?

A.—Harden at the ends only, and polish one-quarter the way up.

383. Q.—In calculating the magnetizing force of a magnet coil does the E. M. F. cut any figure in the case? Suppose that in two differ-

ent cases the current in amperes and the number of turns are the same, but in one case the E. M. F. is 55 volts, while in the other case the E. M. F. is 110 volts, will there be any difference in the strength of the fields?

A.—The strength of the field magnets depends upon the ampere turns. The voltage has nothing to do with it, except that it determines the number of amperes. Should the voltage of a given magnet coil be doubled, the amperes would be doubled. With two magnets having the same number of turns, but one of double the resistance of the other, the larger resistance having double the voltage behind it, the amperes and the magneto-motive force would be the same in both cases. We assume that our correspondent understands the influence of the size and material of the core on the actual strength of the magnet.

384. Q.—What is the loss of effect due to the resistance of the conducting medium for various distances?

A.—The following figures are given for the power wasted when the pressure at the entrance is 200 volts:

Horse-power Transmitted.	Horse-power Wasted, 1 Mile.	Horse-power Wasted, 10 Miles.
10	1.676	8.620
50	8.38	43.10
100	16.76	86.2

For a pressure of 2,000 volts the actual wastage is much less:

Horse-power Transmitted.	Horse-power Wasted, 1 Mile.	Horse-power Wasted. 10 Miles.
100	1.716	16.763
500	8.58	83.815
1,000	17.16	167.63

385. Q.—What is the horse-power required to run an incandescent light of different candle-powers, and also of an arc light?

A.—An incandescent lamp requires about 15 watts per candle, so that a 16-candle lamp should require $15 \times 16 = 240$ watts, or $\frac{240}{746} = .32$ horse-power. An arc lamp requires about 3 watts per candle, so that a light of 200 candles would require $200 \times 3 = 600$ watts, or $\frac{600}{764} = .804$ horse-power. The nominal candle-powers of lamps, especially of arc lamps, vary widely from the actual candle-power,

386. Q.—Is a No. 6 B & S gage copper wire large enough to supply current for 300 16 candle-power lamps at 110 volts? What formula gives the capacity of electrical conductors?

A.—No; the current is beyond the capacity of the wire, to say nothing of reasonable drop in pressure. The following formula gives directly the size of wire for a given number of lamps:

$$A = \frac{2150\ W L N}{a L^2} = 119{,}500$$

which calls for wire of No. 0000 B & S gage. The percentage of drop allowed is proper for lamps which are to be burned promiscuously. In case the lamps are to be all on or all off the percentage might be increased to 10, with marked economy of wire.

387. Q.—W refers to our use of the term "current of 2,500 volts," in a note referring to the cutting down of live wires, and asks if it is permissible to use the term volts as a measure of current.

A.—As you understand it—no. The voltage measures the pressure only of the current. The term was used in the note referred to because the voltage indicates the degree of danger in handling a live wire, which in this case was such that most men would prefer to let it alone—same as a buzz-saw in motion.

388. Q.—How is it best to magnetize a permanent steel magnet, and what weight should it hold?

A.—The best method of magnetizing is to pass a coil, through which a current is flowing, over the magnet from end to end. If you have no such coil it may be done by rubbing on the poles of another magnet, either permanent or electro, but better the latter. Begin with contact on one end of your bar, and draw its whole length over the pole, breaking contact at the opposite end. Repeat this several times. The magnet cannot be given the strength which you expect. You should be satisfied if it will hold its own weight. The holding power may be increased by reducing the contact surfaces at the ends, which should be done before magnetizing, as shocks and jars tend to destroy the magnetism. A good joint between the poles and keeper will also assist the holding power.

389. Q.—In connecting an outhouse with a dwelling house by a burglar alarm can I lay common wire underground in iron pipes? Is a sal-ammoniac battery suitable for this purpose?

A.—No; you should use wire properly insulated for the service. Consult the manufacturer of such materials. Yes; if the alarm is to be, as practically all of them are, of the open-circuit type; that is, open under normal conditions and closed when the alarm is ringing.

390. Q.—How can I demagnetize a pair of calipers?

A.—Hang them from a twisted string near a strong magnet, and as they revolve from the untwisting of the string remove them gradually from the vicinity of the magnet. They should be opened out and revolve in the plane of their length.

391. Q.—What materials are used for lining electroplating tanks? Are bare wood tanks practicable?

A.—For lye and cyanide solutions bare wood tanks are practicable, yellow pine being the best wood.. For acid solutions the wood tanks should be lined with asphalt tempered with rosin. The percentage of rosin depends on the quality of the asphalt, and may be determined by a little experimenting.

392. Q.—What size and number of battery plates will be required for a 30-ampere hour cell?

A.—We assume that this inquiry relates to secondary or storage batteries. If so, the size of the plates will depend, in part, upon the rate at which the cell is to be discharged, and also upon its construction. For the ordinary lead plate cell 1 square foot of surface of positive plate, or 2 feet for positive and negative combined, will deliver about 7 amperes for ten hours, equal to 70 ampere hours. The same size plates, if forced up to a discharge rate of 15 amperes, will only keep it up for three hours, thus reducing the ampere hours to 45. The first named is a fair rate of discharge, and on this basis the total plate surface should be at the rate of 1 square foot for about 35 ampere hours capacity.

393. Q.—How does a dynamo generate current to energize its field magnets when starting? Without a flow of electricity through the field coils there is no magnetism, and without magnetism the dynamo will not generate electricity.

A.—Iron which has once been magnetized retains a small amount of magnetism, called residual magnetism, after the magnetizing influence has been withdrawn. This residual magnetism is sufficient to generate a small current, which immediately

strengthens the magnetism, and this in turn strengthens the current, and in this way the full power of the machine is reached. While the action is successive in this way, it is all done so quickly as to be almost instantaneous. This explanation shows why a machine that has once been operated should start itself again. When the magnetic influences in an electrical works are considered, it will be seen that the magnets of dynamos can hardly fail to receive some magnetism in the process of manufacture, and they do, in fact, become thus sufficiently magnetized—with rare exceptions—to start themselves the first time they are put in motion.

394. Q.—I have a small dynamo for incandescent lighting. The armature is wound with wire of 24 gage and the field coils with 27 gage. At 4,200 revolutions per minute the machine gives 52 volts pressure. I want to reduce the speed to 3,200 and raise the voltage. What changes in the wiring are necessary?

A.—Since the field wire is smaller than that on the armature, it is evident that the machine is shunt wound, and this being the case the voltage can be increased to some extent by enlarging the field wire, as thereby the current through the field coils will be increased. The gain that can be effected in this way will depend upon the density to which the field is magnetized. Generally the fields of small machines are magnetized about as high as it is advisable to go, and in that case very little can be gained by enlarging the wire. Under the most favorable circumstances the voltage cannot be increased by this expedient more than 10 or 15 per cent., and to accomplish even this much it is necessary to make a considerable increase in the size of wire, owing to the fact that if the current passing around the field coils is doubled the strength of the field is not increased more than 15 or 20 per cent., and in many cases even less than this. The best way to obtain the increased voltage is by rewinding the armature with a smaller wire and greater number of turns. As you desire to run the machine at 3,200 instead of 4,200 the armature turns should be increased in the proportion of about 46 to 32, the increase in turns being greater than the difference in speed, so as to allow for the greater resistance of the armature. This change would increase the voltage, but at the same time it would reduce the capacity of the machine, as the armature wound with small wire could not carry as much current.

Gas Engine.

395. Q.—In the ignition of gas or oil vapor, or the explosion of gunpowder in a closed vessel, is the pressure produced a permanent one, or only instantaneous and then dying away to nothing?

A.—The pressure is a "permanent" one, or at least as much so as the steam pressure in a steam engine. Indicator diagrams taken from gas engines show that the engine is not driven by the direct act of the explosion, but by the gradual expansion of the gas throughout the stroke succeeding the explosion.

396. Q.—In the gas engine the gases are ignited, causing an explosion and consequent pressure, which drives the piston; on the return stroke the burnt gases are expelled. Now, if it were possible to block the wheels so as to hold the piston at any point on the power stroke, then introduce the gas and air in proper quantities, ignite and explode the gas, how long would the resultant pressure remain in the cylinder? In other words, is it a sudden expansion that must be used at once, or is it a pressure created by the liberation of so many heat units?

A.—By exploding the gas a pressure is produced, and this pressure will not be changed so long as the temperature and volume remain unchanged.

397. Q.—What is the best material for the piston rings of a gas engine, and what should be the size and number of rings for a 6-inch piston?

A.—Make the rings of cast iron, using three or four rings, ⅜ inch wide, each sprung into a separate groove, the ends abutting as closely as possible when the ring is in place.

398. Q.—Should the piston be reduced in diameter at the explosion end?

A.—The usual practice is to make the piston of uniform diameter, but to bore the cylinder slightly larger at the back, or explosion end.

399. Q.—Must take-up be provided for the piston end of the connecting rod?

A.—The rod is usually made with a solid eye, and without adjustment at that end.

400. Q.—In making pistons for gas engines what is the best material for rings, and how are they fitted? Is the piston made a close fit, or is it slack and the rings depended on to make it gas-tight? Are the rings usually placed singly in each groove, and if so, why? Would not two rings in each groove with the split sides diametrically opposite be good?

A.—We have looked into the practice of the De La Vergne Refrigerating Machine Company, of this city, in their construction of the Hornsby-Akroyd gas engine. By the kindness of Mr. George Richmond, of that company, we were lately permitted to examine a 16-inch cylinder and piston belonging to an engine which had been running three years. The cylinder, trunk piston and rings were of cast iron. The rings, of which there were four, placed, of course, near the inner end of the piston, were about ⅝ inch wide, and each sprung into a separate groove, with about ½ inch between the grooves. The ends of the rings had each a rectangular projection one-half the width of the ring, one on one side and the other on the other side, lapping by each other and the ends coming very close together when the ring was in position in the cylinder. The piston was fitted to just slip into the cylinder. It was understood that in boring the cylinder it was made slightly larger at the inner end near the combustion chamber to allow for the effects of the heat. Some experience must, of course, be necessary to secure precisely what is best in these conditions. The wear shown in the cylinder examined was quite small. Where the rings had traveled the marks of the boring tool had disappeared on the lower side of the cylinder, while on the upper side they were not all obliterated, and the entire surface showed a beautiful glaze, without scratch or cut. The wear was less than we would have expected to see in a steam cylinder after running as long. Two rings in a groove have, of course, been tried, but the single ring in each groove seems to have prevailed.

401. Q.—Why are all gas or gasoline engines made with a center crank instead of a side crank?

A.—We are not sure that all such engines are so made. They are generally made with a center crank for the sake of having each engine self-contained and complete in itself. If a side crank was used an outboard bearing would be necessary,

and that would necessitate a careful and accurate setting and maintenance of both engine bed and outboard bearing to keep the shaft in line. The heavy flywheels which engines of this type carry also probably have to do with determining the arrangement of bearings.

402. Q.—What degree of compression is usual in gas engine practice?

A.—There is no "usual" degree of compression, for the reason that this depends entirely on the size and type of the engine. A good basis is to make the clearance volume 45 per cent. of the net volume of the stroke, which gives roughly 70 pounds compression (absolute). This is about the limit for short-stroke engines of 4 to 5 inches bore, and must be cut down for smaller ones. For larger bores or relatively longer strokes the compression may be somewhat increased; a clearance volume of 37 per cent., giving about 90 pounds, being permissible for 6x12 inches four-cycle engine. It is not practicable to go much beyond this, except for dilute fuel gas, as it takes but little to ignite the charge spontaneously at this pressure. It is very necessary, when working with any but the lowest compressions, to design the sparker so that it cannot overheat; and in general it is impracticable to use as high a compression in two-cycle as in four-cycle engines, on account of the rapid heating of the sparker and other exposed parts.

403. Q.—What is considered about the best device for feeding gasoline to a gasoline engine?

A.—For engines of moderate size a very satisfactory and simple method is to pump the gasoline through an overflow cup, from the base of which a short tube projects into a horizontal section of the air-supply pipe, terminating in an adjustable needle orifice a little above the normal level of the gasoline in the cup. The slight vacuum in the pipe will then suck in a spray of gasoline, which is self-regulating within fairly wide limits of speed. If necessary, the mouth of the pipe may be partially closed by a permanent obstruction. It is highly desirable that the gasoline be completely vaporized and commingled with the air before it enters the cylinder (or, if the engine be of the two-cycle type, the crank case); and to effect this a sufficient length of pipe, with or without baffles, must be interposed between the point of injection and the cylinder, or the air must be warmed by being

drawn through an air-jacket around the exhaust pipe. To start the engine a small quantity of free gasoline may be introduced into the air pipe. If the engine governs by throttling, it must throttle on both sides of the point of injection to preserve the vacuum unchanged.

404. Q.—In using a carburetter for gasoline engines is it necessary to heat the air before it enters the carburetter?

A.—In some engines the air is not heated, and in others it is heated by passing through a jacket on the exhaust pipe, so that it can hardly be said that the heating is necessary.

405. Q.—Is the air usually pumped into the carburetter, or does the engine draw it in by the suction of the engine?

A.—The air is drawn in, or through, by the motion of the piston.

406. Q.—How much air does 35 cubic feet of gas require to support combustion? Bunsen burners are used and the gas is from the city mains. What effect does the product of this combustion have upon the air of the room, 35x18 feet, 9 feet high, with no special means of ventilation except the cracks around six windows and a 7x9-inch opening in the skylight? These questions relate to a linotype plant using 35 feet of gas per hour, with probably double that amount at first and until the metal acquires the working temperature.

A.—The Mergenthaler Linotype Company replies that "the opening specified is manifestly too small for such a room in which men are working and gas is being burned. Our machine contains a hood over the melting pot, from which it is customary to extend a small tin or copper pipe to a chimney or other outside opening. If this is done no further trouble will be experienced from heat or fumes, though the fact is that a number of our machines are run without any special provision for ventilation and without trouble." One ordinary gas light equals in vitiating effect about 5½ men.

407. Q.—Can benzine be used in place of gasoline in an explosive engine?

A.—Not without the use of heat to assist vaporization. Benzine and gasoline differ in gravity, the former being about 58 or 60 degrees, while for gasoline engines the gravity of the fluid should not be lower than 68 degrees, and 74 is much better.

There is a class of engines, more largely used in Europe than here, which employs the heat of the exhaust to vaporize the oil, and uses benzine. Of this class are the Priestman and the Hornsby-Akroyd.

408. Q.—Please explain the workings of the oil engine valves. How is the letting into the engine of such a small quantity of the oil at a time accomplished, and how is the air drawn into it in just the exact quantity?

A.—The special device employed for delivering the oil varies with the different makes of engine. In the Hornsby-Akroyd engine a pump runs constantly which is capable of delivering the largest charge ever required, and a ball governor works a by-pass which operates at an earlier or later part of the pump stroke as more or less power is required, the surplus oil being allowed to flow back to the tank. The air is allowed to fill, or nearly fill, the entire cylinder for each charge, the volume of air admitted being constant, regardless of the charge of oil.

409. Q.—How many ⅞-inch stud bolts should be used on a gas engine cylinder head with an inside diameter of 11 inches, the centers of the stud being 1½ inches from the bore, and assuming an initial pressure of 200 pounds?

A.—The studs should be numerous enough and near enough to each other so that the flange will not spring away and leak midway between them. The tensile strength of the studs is usually largely in excess of the pressure to be resisted. In this case we would use twelve studs. The total pressure against the head would be $11^2 \times .7854 \times 200 = 19{,}000$ pounds. Assuming 20,000 pounds per square inch for the tensile strength of the studs, their united strength would be $.73^2$ (diameter of bottom of thread) $\times$ $.7854 \times 20{,}000 \times 12 = 100{,}440$ pounds, and the ratio of their strength to the pressure against the head would be $100{,}440 \div 19{,}000 = 5.28$.

410. Q.—Please explain the meaning of indicated and actual horse-power of gas engines, frequently given in catalogs.

A.—The indicated horse-power is calculated from the mean effective pressure in the cylinder determined by an indicator. The actual or net horse-power is calculated from the pressure exerted by the engine in doing useful work, which can be determined by a dynamometer; in short, the net horse-power is the

indicated horse-power minus the power required to overcome the friction of the engine.

411. Q.—How much liquid gasoline does it take to make a charge for a gasoline engine to the cubic foot of free air?

A.—The best gasoline engines use about one-tenth gallon per horse-power; but as the engines are governed by the quantity of gasoline admitted while a constant speed is maintained, the ratio of gasoline to air volume is constantly changing.

412. Q.—We have an Olds & Son gasoline engine, 7x12 inches, running 265 revolutions per minute; please let me know what the explosive power is in an engine of this type.

A.—The engine does not run by "explosive" power, but by the expansion of the exploded charge, and the power developed may be ascertained by an indicator, as with a steam engine, or by some form of brake or dynamometer. The Olds engine is of the four-cycle compression type, and if the mean effective pressure for the working stroke was 50 pounds, it would develop 6 or 7 horse-power.

413. Q.—What is producer gas?

A.—It is the gas resulting from passing steam and air through a bed of incandescent coal. The coal is held in a receiver or gas producer fitted with suitable grate bars and other attachments which will maintain the proper incandescence of the fuel bed. The quality of this gas will depend on the quality of coal used and the conditions of manufacture. When air alone is passed through the incandescent fuel the resulting gas is termed "air gas."

Marine.

414. Q.—What are the comparative pressures on the thrust bearing of a steamship when the ship is in motion and when tied up at the dock?

A.—Seaton's formula for the thrust is as follows:

$$P = IHP \times \frac{217}{K}$$

in which

P = the pressure in pounds,

K = the speed of the ship in knots per hour.

In interpreting this formula the speed of the ship is to be understood as the speed through the water, and not past a stationary object on shore. If taken as the absolute speed, the value of P would, of course, be infinite when the ship is tied up, which is obviously impossible. When the ship is tied up the power of the engine is expended in setting up a current of water past the ship, the speed of which must be known in order to apply the formula. The value of this would obviously depend on circumstances; a boat moored in midstream, for example, being under very different conditions in this respect from one tied up in a ferry slip, and what average values would be we have no means of knowing.

415. Q.—What is meant by the pitch of the screw of a steamer, and how is the speed calculated from the number of revolutions?

A.—The pitch of a screw propeller is understood in the same way as the pitch of any other screw. It is the distance which any point in a blade will travel in the direction of the axis during one revolution, assuming that there is no slip. Multiplying the number of revolutions (N) per minute by 88, and dividing the product by the pitch of the screw in feet (P) will give us the speed in miles per hour (V), without slip: $\frac{88\,N}{P} = V$. The slip may vary from to per cent. up to 50, or more, depending

upon the ratio of screw area to the submerged section of vessel and various matters that we have not space to go into.

416. Q.—If the forward eccentric strap should break on a small marine engine, what could be done so as to reach port?

A.—Repair the strap, or substitute something for it. If the outer half of the strap should break beyond repair it might be possible to hold the other half to the eccentric by means of a spring attached to the valve rod joint. A spring might be improvised out of an oar, or something similar. As to devising some other valve motion, we would prefer to have a sketch of the engine.

417. Q.—Does the patent log of a ship indicate the speed of the vessel when running against a current, or does it indicate the difference between the two speeds?

A.—The log indicates the speed of the vessel (if running with the current) plus the velocity of the current. To get the speed of the vessel the velocity of the current must be deducted from the speed shown by the log.

418. Q.—How many grades, or numbers, of Parson's white brass are used by marine engine builders?

A.—Parson's white brass, No. 2 quality, is used by marine engine builders for facing and lining bearings; its composition is: Tin, 68; zinc, 30.5; copper, 1, and lead, 0.5. Another composition is: Tin, 68; antimony, 1; lead, 2; copper, 2; zinc, 27. These are the only two grades of Parson's white brass that we know of.

419. Q.—What is considered the average amount of slip of propellers, and what is the least amount of slip known?

A.—It is impossible to say what is the average slip of propellers, as it ranges from 100 per cent. positive to 15 per cent. or more apparent negative slip. The average will, of course, vary with different kinds of work and different models of hull. With high speed, free-running craft the slip would be very different from that of a tugboat.

420. Q.—We are getting up designs for several small compound marine engines, cylinders 3 and 6 by 4 inches; the writer would prefer to set the cranks at 180 degrees; what is the general practice, and which gives the best results?

A.—The general practice is 90 degrees, and it should give as

good results as the other with sufficiently roomy connections, and especially with a reheater.

421. Q.—I am taking a mechanical course at college and expect to graduate this year. I wish to become a marine engineer, and hope to take that course at another college as a post graduate student. What kind of an opening is there for a college graduate in that line, and also what are the usual wages?

A.—Graduates generally enter the drawing room of a machine shop, but there are some who enter the shop so as to become familiar with the practical part of the business. You should have comparatively little or no difficulty in finding a suitable position, for we have been informed by professors that frequently the demand for bright and capable graduates exceeds the supply. The wages depend greatly on your own ability and industry.

422. Q.—What is understood by the pitch of a propeller?

A.—It is the distance which any point in the blade, describing a helix, will travel in the direction of the axis during one revolution, the point being assumed to move around the axis. From this definition, the pitch of a propeller with a uniform pitch is equal to the distance a propeller will advance during one revolution, provided there is no slip. In a case of this kind the term "pitch of the propeller" is analogous to the term "pitch of the thread" of an ordinary single-threaded screw. In the latter the pitch is the distance, measured in the line parallel to the axis between two adjacent central points of the thread, and it is equal to the distance that the screw will advance during one revolution. The pitch of a propeller having a uniform pitch may be defined in a similar way. Assume that one blade extends clear around the axis so as to form one continuous thread all around the shaft, then the pitch is the distance between any two adjacent points in the surface of action lying in a line parallel to the axis. Sometimes propellers have a varying pitch; in such cases the point in the blade at which the pitch is to be measured must be given. In such a case the pitch is equal, according to the first definition, to the distance the given point will travel in the direction of the axis during one revolution of the propeller, provided there is no slip at that point.

423. Q.—What is needed to make the jet propulsion of ships a success?

A.—Some new laws in mechanics which will prove other established laws to be incorrect.

424. Q.—Has the screw of a small steam tug any tendency to roll or cant the boat while in motion in the water, either one side or the other?

A.—There is some tendency to roll the boat in the opposite direction from that in which the screw turns.

425. Q.—What is the rule for finding the tonnage of a small boat?

A.—There are various kinds of tonnage measurements actually in use. For instance, there is the displacement tonnage, register tonnage, freight tonnage, yacht and boat sailing tonnage, and various other kinds. Some of these "tons" represent dead weight, others represent capacity, and some are empirical measures representing neither weight nor capacity. With such a variety of measures and so many kinds of tons careful discrimination is obviously needed to prevent mistakes when dealing with the tonnage of ships. The displacement or gross tonnage is sometimes approximately estimated as follows: Let L denote the length in feet of the boat, B its extreme breadth in feet, and D the mean draft in feet; the product of these three dimensions will give the volume of a parallelopipedon in cubic feet. Putting V for this volume we have: $V = L \times B \times D$. The volume of displacement may then be expressed as a *percentage* of the volume V; this percentage varies for different classes of ships. In modern racing yachts with very deep keels the percentages vary from 22 to 33; in modern merchantmen the percentages frequently lie between 55 and 60; for ordinary small boats probably 50 will give a fair estimate. If the length is 20 feet, breadth 5 feet and mean draught 2 feet, we have $20 \times 5 \times 2 = 200$ cubic feet for the volume of the parallopipedon; and $200 \times \frac{50}{100} = 100$ cubic feet of displacement. There are 35 cubic feet of sea water to the ton; hence $\frac{100}{35} = 2.8$ tons displacement. Of course, this must be taken only as an approximate estimate. For an accurate computation we require the lines of the boat, and considerable labor will be involved. The registered tonnage is that which has commercial value, and is found by the rules laid down in an act to regulate the admeasurement of tonnage of ships and vessels of the United States.

426. Q.—Why do sea-going steamers have their funnels inclined backwards instead of set vertically?

A.—So that they may have a uniform rake with the masts; otherwise the general appearance would not be pleasing.

427. Q.—Two boats are placed side by side in dead water. A rope is tied to the bow of one and pulled to the shore by one man. The other to be pulled by two men, one to stand at the bow with rope in hand, pulling hand over hand, while the other man is pulling in the same manner on the same rope from the shore. Now, which boat will reach the shore first? All the three men have equal strength.

A.—The boat pulled by one man will reach the shore first, because he has the weight of one man less to pull. But if you put a weight in one boat equal to the man in the other boat, both boats will reach the shore at the same time. This cannot be otherwise, because the pull on the rope in one case is equal to the pull on the rope in the other.

428. Q.—I am a machinist with eight years' practice at the business, but would like to become a marine engineer. How should I proceed to gain that end?

A.—We should advise you to seek employment as a machinist in a shop where marine engines are built, and show by your conduct and faithful attention to business that you are worthy of confidence, and that you have the ability for becoming an engineer. In these shops you will come in contact with chief engineers of steamers to whom you may state your desire, and, if you are worthy of it, your employer will doubtless interest himself in your welfare and aid you in gaining your ends. Another way would be to apply to chief engineers on steamers at once for a position as assistant, but we believe the first way is the best; we have seen several young men follow it who were rapidly promoted.

Power Transmission.

429. Q.—What makes a belt adhere to the face of a pulley so that it can transmit power?

A.—The adhesion of a belt to the pulley is due, primarily, to the tension given the belt, which pulls it to the face of the pulley. This incidentally excludes the air from the surfaces between the pulley and belt, and the pressure of the atmosphere outside may then help to press the belt to the pulley; but whether the atmospheric pressure has anything to do with it or not, the belt is driven or drives a pulley by friction only. Friction may be defined as that force which resists relative motion between two bodies which are in contact with each other.

430. Q.—What is the simplest rule for calculating the power transmitted by belts, either single or double?

A.—Multiply the width of the belt in inches by the number of feet of belt travel per minute and divide by 600 for single belt and by 400 for double belt; the result will give approximately the horse-power which may be safely and surely transmitted. Thus, a single belt 4 inches wide, running 900 feet per minute, will transmit $4 \times 900 \div 600 = 6$ horse-power. A double belt 12 inches wide, running 1,000 feet per minute, will transmit $12 \times 1{,}000 \div 400 = 30$ horse-power.

431. Q.—I have seen it stated in print that the total tension on the two sides of a belt is constant, or that it is the same whether the belt is driving or at rest, the driving effect when running being due merely to the difference in tension of the two sides. Is this correct?

A.—It cannot possibly be correct in all cases. We have seen in a reputable engine manufactory the main belt running up from the pulley on the engine shaft at an angle of about 45 degrees to the pulley on the line shaft, the slack side of the belt on top, and sagging so that it almost touched the lower or pulling belt. When the engine was stopped there could have been practically no tension on either side of the belt, while when running the pull on the lower side was probably 700 or 800 pounds.

432. Q.—I have a main driving belt that has become too slack. It is a 36-inch double endless belt; distance between centers of shaft, 36 feet; driving pulley, 15 feet diameter; driven pulley, 4½ feet diameter; revolutions of engine, 75. Would you advise me to cut a piece out of the belt and lace it, or would you advise the use of a tightener?

A.—By all means shorten the belt. If you are not so situated that you can shorten it, making it endless as now, then cut and lace it.

433. Q.—If the tension per square inch of a belt 3.5 inches wide and .25 inch thick is 284 pounds, how do you compute the tension per inch of width of this belt?

A.—We have found the cross-sectional area of this belt to be .875 square inch, hence the tension on the belt will be $284 \times .875 = 248.5$ pounds, and per inch of width of belt the tension will be $\frac{248.5}{3.5} = 71$ pounds.

434. Q.—A belt 3½ inches wide and .25 inch thick has a tension of 71 pounds per inch of width, what will be the tension per square inch?

A.—The cross-sectional area of the belt is $3.5 \times .25 = .875$ square inch, and the whole tension on the section will be $71 \times 3.5 = 284.5$ pounds; hence the tension per square inch will be $\frac{248.5}{.875} = 284$ pounds.

435. Q.—What is a good method of removing oil from a belt which has become saturated?

A.—The best method we know is to make a liberal application of powdered chalk.

436. Q.—What horse-power will be transmitted by a double belt 24 inches wide, running on two pulleys, each 69 inches diameter and 125 revolutions per minute?

A.—Allow 50 square feet of belt per minute to transmit 1 horse-power. The square feet of belt per minute in this case will be 5.75 (diameter of pulley in feet) $\times$ 3.14 $\times$ 2 (width of belt in feet) $\times$ 125 $\div$ 50 = 90.275 horse-power. Some authorities give not over 40 square feet of belt per horse-power for double belt, which would give a result 25 per cent. higher than the above. The belt will probably easily transmit 100 horse-power.

437. Q.—I claim that a belt will run to the slack side of the pulley. Am I right?

A.—When the two shafts are parallel the belt will run on that part of the pulley that is of the largest diameter. If the shafts are inclined towards each other the tendency of the belt is to run off the pulleys towards the ends of the shafts that are nearest together.

438. Q.—Which is the proper and best side of a belt to put on the pulley, the rough or the smooth side; and what percentage of wear does one side have over the other?

A.—The strongest part of belt leather is near the flesh side, about one-third the way through from that side. It is therefore desirable to run the grain (hair) side on the pulley, in order that the strongest part of the belt may be subject to the least wear. The flesh side is not liable to crack, as the grain side will do when the belt is old; hence it is better to crimp the grain than to stretch it. Leather belts running with the grain side to the pulley will drive 30 per cent. more than with the flesh side. The belt as well as the pulley adheres best when smooth, and the grain side adheres best because it is smoothest.

439. Q.—Should a belt be placed so that the splices on the inside will point toward the direction of motion or against it?

A.—It depends upon the pulley on which the belt slips. If it slips on the driving pulley the splice should point in the direction of the motion, but if it slips on the driven pulley it should point opposite to the motion. A belt so placed will obviate any tendency of the slipping to curl up the edge of the splice. At the same time we think it is very seldom that any attention is paid to the matter.

440. Q.—Why is it that a horizontal belt gives better satisfaction when the slack side is on top? Of course, we have a greater arc of contact, but is not the total stress in the belt the same? And since friction is independent of areas in contact and directly dependent on the pressure, I fail to see why a belt gives better satisfaction when running as above, although I know it is so.

A.—When the slack side of a horizontal belt is on top the tension will be greater than when the slack side is on the bottom. Under the former condition the weight of the belt will act against the centrifugal force of the belt; and when the slack

side is on the bottom the weight of the belt will act in conjunction with the centrifugal force to decrease the tension. By having the slack side on top the arc of contact will be increased, which has been proved to be another advantage.

441. Q.—Is it possible to transmit 20 horse-power through a 6-inch belt running over 30-inch pulleys which make 165 revolutions per minute? We have had fifty cards taken off the engine, and when figured by experts the cards show all the way from 16 to 20 horse-power consumed by our department. Still we fail to see how a 6-inch belt traveling at the velocity above named can transmit 20 horse-power, when all the calculations laid down by manufacturers and others give 15 horse-power transmitted by the belt. The engine furnishing the power is a 12x12-inch engine, running at 165 revolutions per minute, with 80 pounds boiler pressure.

A.—The rules for computing the horse-power transmitted by belts give the horse-power which a belt should transmit with safety and not the ultimate horse-power which a belt can transmit. It is, therefore, quite possible that your belt does transmit 20 horse-power, although this overstrains the belt. The engine is quite capable of developing 33 horse-power; indeed, it should develop more.

442. Q.—In crowning the pulleys what is the rule for finding the proper curve?

A.—There is no uniformity in practice; even the form of the face varies. Some makers adopt a curved face and others adopt a straight line from the center to the edge of the face, thus forming two frustums of a cone. For pulleys having a face wider than 4 inches, the taper each way from the center should be ¼ inch per foot; if curved, the convexity should be the same. When the face is less than 4 inches wide, ⅜ to ½ inch per foot is not too much.

443. Q.—We have a 48-inch pulley on a shaft which is to be driven at 175 revolutions per minute. Now, suppose the engine crank shaft has on it a pulley of the same diameter—that is, 48 inches—and the engine runs at the same speed (175 revolutions), will it require the same width of belt as would be required if the pulley on the engine shaft were 24 inches diameter and the engine running at 350 revolutions per minute?

A.—As the belt speed under the two conditions named would be the same, and the same work would, of course, be done, the width of the belt would be practically the same. Some difference might result, however, from the fact that when using the smaller pulley on the engine shaft the belt contact on this pulley would be for an arc of less than 180 degrees, and if the pulleys are quite close together this decrease of the arc of contact might make a difference and require a wider belt to overcome it; but unless the width of the belt is quite closely calculated for the work to be done there will be no practical difference in the two cases.

444. Q.—How shall I ascertain the proper distance between centers of a pair of cone pulleys whose diameters are known, so that the tension on the belt will be the same on each step? Say, for instance, that both cones are alike, and that there are three steps—16, 18 and 20 inches diameter, respectively.

A.—The question, of course, assumes that the diameters are right for some distance, which those given above probably are not, absolutely, although they may be "near enough." The difference in diameter between the smallest pulley and that next larger should be somewhat greater than the difference between the largest pulley and the next below it. We would draw circles corresponding to all the steps of one pulley and then those of the other pulley, quite near to them, and then draw the second pulley again at a considerably greater distance. Upon drawing the belt lines it would immediately appear which position was most correct; and one or two trials at other distances, if necessary, should give the required distance between the pulleys with sufficient exactness.

445. Q.—To what extent is the driving power of a belt affected by the diameter of the pulley over which it passes, it being understood that the pulley in all cases is to be wrapped one-half of its circumference, and the tension and velocity of the belt to remain unchanged? In other words, will not a pulley 12 inches diameter, running at a speed of 1,000 turns per minute, transmit as much power as one 24 inches diameter running at a speed of 500 revolutions per minute?

A.—The power that can be transmitted by the two pulleys should be precisely the same, and within practical limits we

think there is no difference by such changes of diameter so long as the belt speed remains the same.

446. Q.—Is it not centrifugal force which causes a belt to run in the middle of a coned pulley?

A.—Centrifugal force has nothing to do with it. The pulley referred to in this case is, of course, a "crowned" faced pulley, or one which is coned or tapered each way from the middle line of the face. The action will perhaps be best understood by first taking a belt running over two straight or cylindrical pulleys on parallel shafts. The pulleys and the belt being perfect, we may assume that the belt will run continually along the same line on the two pulleys, with no tendency to move edgewise in either direction. If, however, one of the pulleys is changed for a taper-faced pulley, or one having a single-coned surface, the belt will immediately begin to crowd toward the base of the cone, or the larger side of the pulley. The pulley being larger in diameter at one side than at the other, is, of course, also larger in circumference there, and that edge of the belt is drawn along faster than the other edge. This draws the part of the belt that is approaching the pulley out of the straight line, and for this reason makes it lead more and more towards the big side of the pulley. If, now, we had another similar taper pulley placed by the side of the other, but reversed so that the big edges of the two pulleys come together, we can imagine the belt to go on crowding sidewise until more than half of the width of it has gone over from the first pulley to the second one, and then, of course, the tendency will be to make the belt lead the other way, and between the alternate action of the two cones the belt is induced to make a compromise between them and to stay in the middle.

447. Q.—A claims that in figuring speed the thickness of the belt should be added to the diameter of the pulley. B claims that it should not be. Which is right?

A.—The whole thickness of the belt should never be added, but a part of its thickness should sometimes be added, whether it should be or not depending upon circumstances. Belts, owing to the fact that they are compressed at their under surfaces and stretched at their outer surfaces in passing over pulleys, have what may be called a pitch line, and which may be taken at two-

fifths the thickness of the belt measured from the pulley. If the pulleys over which the belt runs differ greatly in size and accurate speed is required, this must be taken into account, especially if one or both pulleys are small in diameter, so that the amount added is a considerable percentage of the diameter. But where the pulleys are of the same size, adding the same amount to each will not affect the result, and unless the variation between them is considerable in proportion to the absolute diameter it may be neglected.

448. Q.—Does a cross belt run harder than an open one, the size of pulleys and distance apart being the same?

A.—Generally speaking, there may be said to be a small loss in the use of the cross belt, but not enough to consider where its use is advisable. Sometimes there is a gain, from the fact that the cross belt is in contact with more of the surface of the pulley and need not be so tight. A crossed belt is not likely to last as long as an open one, and where the latter can be used it is generally advisable to do so.

449. Q.—I had a belt 5 inches wide, 48 feet long, which was running on 16-inch pulleys, turning 198 revolutions per minute. It did not transmit the power required, and consequently I replaced it by a 6-inch belt, which, running at the same speed, gives the power required. Now, what diameter of pulley would have been needed to replace the 16-inch ones in order to get a corresponding increase of power with the 5-inch belt?

A.—By increasing the width of the belt 1 inch you increased its capacity 20 per cent. To give it the same increased capacity by increasing its speed you would need pulleys 20 per cent., or one-fifth, larger, which would be 19.2 inches. Consequently 20-inch pulleys would have given you the required increase, with something to spare.

450. Q.—What is the cause of some belts making a horrible screeching noise when shifted from the loose to the tight pulley, and what is a remedy?

A.—The cause of the noise is the slipping of the belt on the pulley, and anything which diminishes the slipping diminishes the noise. This may be done sometimes by tightening the belt. But if the belt is tight enough, give it plenty of belt oil, which will be almost sure to stop the noise, and will benefit the belt.

451. Q.—A main shaft in a shop has been lined up as nearly as possible with the crank shaft of the engine. The driving belt runs in the center of the flywheel, but it runs to one side on the driven pulley. The supports are so close to the driven pulley that it cannot be moved on the shaft far enough to make the belt keep in the middle of it. The pulley is 2 inches wider than the belt. Now, what is the fault, if the shafts are parallel? If not parallel, how should the main shaft be moved to make the belt run in the center of the pulley? Does a belt always climb to the high side?

A.—In cases of this kind the belt crowds towards the ends of the shafts which are the nearer to each other, and to make the belt crowd the other way the other ends of the shafts should be brought nearer together by moving one or the other. If the shafts are absolutely parallel it is still possible for the belt to crowd to one side or the other if both halves of the pulley are not alike. Also, if one edge of the belt has stretched more than the other this would tend to run the belt to one side, and it might be corrected by changing the belt to run the other way.

452. Q.—What lubricant or compound will make raw hide, used for belting purposes, more soft and pliable?

A.—Charles A. Schieren & Co. answer this question as follows: "We do not know any particular lubricant more suitable than any other for raw-hide belting. Our idea in regard to belt dressing is this, viz., that the manufacturer of the belting should be consulted on this subject; what is good for the belting when it is originally made, in the line of a belt dressing (because all belts have been dressed when new), is good thereafter, and the best thing is to use the same article, and then hold the belt responsible for its acts. Getting a foreign substance afterward is as much as to say that it was of no consequence what the belt was dressed with when it was new, and lots of belts are injured by parties putting some concoction worse than a patent medicine on their belts, because some of these wiseacres traveling around the country state it is good. We believe if you will recommend your readers to use the belt dressing that the maker of the belt recommends it will be more in their interests than anything else. However, tallow is supposed to be a very good thing for raw hide, we should imagine."

453. Q.—In the case of two pulleys, one 12 inches and the other 24

inches diameter, will the 24-inch one drive the 12-inch at twice its own speed?

A.—If they are friction pulleys running in contact, without slip, it will. If they are at a distance from each other and the driving is done through the medium of a belt, then the small pulley will be driven at something less than twice the speed of the large one. In making the calculations of the speeds an amount equal to the thickness of the belt should be added to the diameter of each pulley.

454. Q.—What is the power of the following belt: Driving pulleys, 16 inches diameter by 16 inches face and 490 revolutions per minute; driven pulley, 72 inches diameter; belt, double, 15 inches wide and total length 71 feet 8 inches; contact of belt on small pulleys, 2 feet 3 inches; on large pulley, 10 feet 3 inches; total length of belt, 71 feet 8 inches, and it makes 30 passes, or turns, per minute?

A.—The data here given are not of the kind that it is pleasant, or, indeed, even altogether safe, to have anything to do with, as they are evidently incorrect. The speed of the belt as given is 100 feet per minute more than that of the periphery of the driving pulley. The contact of the belt on the small pulley is more than a half of the periphery, which is impossible, unless there were an idler-pulley to lead it around farther; and then, or even without that, the contact around the large pulley is not as great as it should be. The driving power of a belt depends upon its tension, and also, more than is generally allowed for, upon the adhesive condition of both belt and pulley surfaces. It is quite customary to estimate the power transmitted by a belt by the number of square feet of belt surface that passes over the pulleys per minute, and for double belts 40 square feet is a common allowance. In the present case the diameter of the driving pulley being $1\frac{1}{3}$ feet, and the revolutions 490, the linear feet of travel will be $1\frac{1}{3} \times 3.1416 \times 490 = 2{,}052$ feet. Then, the belt being $1\frac{1}{4}$ feet wide, the number of square feet of belt per minute will be $2{,}052 \times 1\frac{1}{4} = 2{,}565$ square feet; and then, $2{,}565 \div 40 = 64$ horse-power. The above practice can be safely followed only when there is not a great difference in the relative diameters of the two pulleys. When there is much difference allowance must be made for the smaller arc of contact on the

smaller pulley. The result above we may assume to be for a contact of 180 degrees, or half-way round. For shorter contacts the result may be diminished in direct proportion to the actual angle. If the angle of contact was 160 degrees, then 180: 160:: 64: 57 horse-power. The method here followed is a rough-and-ready one; but more exact methods would not give any more reliable results in ordinary belting practice.

455. Q.—Would it require as much steam to run an engine with the main belt slipping as it would if the belt did not slip?

A.—This question calls for various answers, or an answer with various qualifications, on account of the different conditions under which slippage may occur. Suppose an engine to be running at a uniform speed, controlled by a governor, and driving a line shaft by a belt with just sufficient strength or tension to drive without slipping. If slipping occurred it would be either from an increase of load on the line shaft or from a decrease in the tension or adhesion of the belt. In either case the speed of the driven shaft would be reduced. The power imparted by the engine is determined by the unbalanced pull of the belt, or the difference between the tension of the two sides. It is generally true that as soon as a belt begins to slip the adhesive friction is reduced, and consequently the unbalanced pull upon the engine wheel and the steam required to drive it would be reduced. If the belt were not, as we assumed at the beginning, doing all that it could do, then an increase of load to the slipping point might leave the belt, save when slipping, with a greater unbalanced pull than when running with normal load, and in that case the steam required would be increased. If, with constant load and uniform driving speed, slippage occurred on account of the weakening of the belt, the steam required would, of course, be reduced in proportion to the decreased belt pull. If we suppose a case in which the driven shaft ran at a uniform speed and constant load, while the engine ran at an increased speed on account of belt slippage, the steam required would be increased. The amount of power, or the foot-pounds, transmitted to the driven pulley in any given time will be the unbalanced pull of the belt in pounds multiplied by the number of feet traveled by the periphery of the driven pulley, but the power exerted by the engine will be measured by the same unbalanced pull of the belt

multiplied by the number of feet traveled by the periphery of the engine pulley. Of course, if there is slip the peripheral speed of the engine pulley will be greater than that of the driven pulley, and the power exerted by the engine, or the steam required, will be greater in proportion to the difference in the peripheral speeds. It not only requires power to drive the driven pulley, but power in addition to this is required to cause the slippage. Slipping belts must always mean power lost.

456. Q.—Does greater velocity increase the strain on a rope hoisting a car out of a shaft, or moving one on a track? If so, in what proportion?

A.—There is some increase due to the greater resistance at high speeds, but more due to the heavier shocks and to the strain of starting, which is not apt to be done so gradually as when low speeds are used. Within ordinary limits the increase would not be serious, but no rule can be given for it.

457. Q.—What size of wire rope would be equivalent to a 2-inch hemp rope?

A.—A wire rope 1 inch in circumference will be equivalent to a hemp rope 2 inches in circumference. The breaking load of each is about 2,240 pounds.

458. Q.—What are the velocities in feet per minute that different sizes of good manila rope should run to transmit 1 horse-power?

A.—For transmitting 1 horse-power the ropes should run at the following speeds:

Diam. of Rope. Inches.	Speed per Minute. Feet.
½	1,034
⅝	652
¾	454
⅞	333
1	260
1¼	164
1½	114
1¾	83
2	73

The basis for this table is the assumption that a rope 1 inch diameter should have a working strain of 200 pounds at all speeds. This is about one-twentieth of the strength of the

splice. This large margin is to enable the rope to perform a large amount of useful work before it is so weakened by wear that it is necessary to be renewed. Many engineers recommend a larger horse-power for the speeds than is given in the table; but we believe that those here given are advisable except in temporary installations. For satisfactory results the diameter of the pulleys should not be less than forty times the diameter of the rope, and as much larger is it is possible to make them. This rule applies also to the idler and tension pulleys as well as to the main driving pulley. The angle of the sides of the grooves in which the rope runs varies, with different engineers, from 45 to 60 degrees. It is very important that the sides of these grooves should be carefully polished, as the fibers of the rope running on the metal as it comes from the lathe tools will gradually break fiber by fiber, and so give the rope a short life. It is also necessary to carefully avoid all blow holes, as they will cut the rope out with surprising rapidity.

459. Q.—What is the best preparation for cooling hot bearings?

A.—Use sulphur and oil on the journal and apply cold water —very cautiously—externally.

460. Q.—Why is lead or tin put into journal brasses after they are finished?

A.—It is done because it is found, for some service and under certain conditions, this lead gives the best results. It is quite largely used for car journals, which, however, is a service differing essentially from that of any other journal.

461. Q.—What is the best way to harden and soften a finished brass journal?

A.—We know of no practical way of hardening such a brass. Brass can ordinarily be hardened only by great pressure, such as that given by a drop hammer or by the drawing process, and this, of course, is not practicable in the case of a journal brass. Brass can be softened by heating to a low heat and plunging in water.

462. Q.—What pressure per square inch will a 2½-inch cast-iron journal stand, running 250 rotations per minute, in a good babbitt bearing?

A.—Allow 100 pounds per square inch of projected area.

463. Q.—What is a safe working pressure per square inch under ordi-

nary circumstances, on babbitted bearings? For instance, what should be the length of a bearing of a shaft 1 11-16 inches diameter; the total pressure on the bearing is 250 pounds, and the shaft makes 5,000 revolutions per minute?

A.—For this high speed we should not allow more than 10 pounds per square inch of projected area. The projected area is equal to the diameter of the shaft multiplied by the length of the bearing. Dividing the total pressure on the bearing by 10, we obtain $\frac{250}{10} = 25$ square inches for the projected area, and dividing the projected area by the diameter of the shaft, we have $\frac{25}{1.68} = 14.8$ inches for the length of the bearing. Even with this length you may have considerable difficulty to run the shaft with the given load at such a high velocity.

464. Q.—What is the limit of pressure to which the journals of high-speed steel shafts may be subjected?

A.—It has been found by experience that when the pressure per square inch exceeds a certain amount the oil or other lubricant is squeezed out, the contact becomes that of metal-and-metal, and the bearing cuts or abrades in spite of even constant lubrication. There is also with every pressure a certain velocity beyond which the bearing will become heated. Hence it may be said that the pressure depends upon the efficiency of the lubrication, the speed, and upon the material of which the bearing is made. It is, therefore, difficult to give the limit of pressure. For line shafting making about 250 revolutions per minute we should aim not to exceed a pressure of 30 pounds per square inch of projected area of the journal. For crank shafts or crank-pin journals this pressure is, of course, much greater, and here even the pressure will depend upon the class of engines, as these work under varied conditions.

465. Q.—What is the formula for regular babbitt metal; also for the cheaper kinds of this metal?

A.—There is but one kind of babbitt metal, and if any alloy is either much better or much worse than that it is not babbitt, but something else. One of the cheaper kinds of the so-called babbitt metal consists of eight parts of lead to one of antimony; the better grades contain less lead and more or less copper and

tin; the real babbitt metal has no lead; it consists of 3.7 parts copper, 7.4 parts antimony, and 88.9 parts tin.

466. Q.—Does increasing the speed increase the friction?

A.—It may or may not, according to circumstances. If we have a journal running at a moderate speed, well lubricated, and with a light load, we may, ordinarily, increase its speed without changing the coefficient of friction, in which case the force required to overcome friction will remain the same; but the moment of the force, or in other words, the power required to overcome the friction of the journal will be increased in proportion to the increase of speed, simply because it is the same force acting through a greater distance per unit of time. But under other conditions, such as where a journal is already running at as high speed as it ought to run with the given load and conditions, lubrication, etc., an increase of speed may increase the coefficient of friction, either by preventing thorough lubrication or by the development of heat faster than it can be conveyed away by surrounding parts or by the atmosphere. The increase of temperature so caused may thin the lubricant or otherwise cause an increase of the coefficient of friction. Under other conditions an increase of speed may, and sometimes does, decrease the coefficient of friction.

467. Q.—Can you give me a rule for the maximum diameter of journals in proportion to the number of revolutions per minute, to run in babbitted bearings, without heating? For instance, what is the highest speed a journal 1½ inches diameter could be run?

A.—Journals may be run at a surface speed of 1,200 feet per minute, or considerably higher than that if lightly loaded. With a pressure of 100 pounds per square inch of bearing a 1½-inch shaft may be run at 3,000 revolutions. The journal should fit the bearing rather loosely.

468. Q.—We wish to run an 18-inch circular saw in our factory and take power from an engine on the other side of an alley which is 18 feet wide. We think of putting a steel shaft across the alley; the distance between the bearings will be 20 feet. What diameter should the shaft be to keep it from sagging when supplying 8 horse-power?

A.—The distance between the bearings is too great; you will have difficulty in preventing deflection. Assuming that the shaft

makes 80 revolutions per minute, you will need a trussed shaft 2½ inches diameter; or another way would be to use a steel tube of larger diameter.

469. Q.—Will you give me a simple formula for the speed of pulleys or shafting?

A.—We assume that what is here meant is a formula for computing the speed of one pulley or shaft when the speed of the driven shaft and size of pulley upon it are known. The best rule for all such problems is the old standard rule of three as given in the arithmetics. Put down for the third term of a simple proportion that number which is of the same denomination as the answer required. Then, if by the nature of the problem the answer will be greater than this third term, put down the greater of the remaining numbers for the second term and the lesser number for the first term. Multiply the second and third terms together and divide by the first; the quotient will be the fourth term and the answer to the problem. For instance, suppose we have a shaft running at 120 revolutions per minute, and it has on it a 36-inch pulley. We wish to drive another shaft at a speed of 300 revolutions, and wish to know what size pulley will be required. Now, since the answer will be a certain *diameter,* or will be stated in *inches,* we, in accordance with the rule above, place for the third term that one of the numbers already known which is of the same denomination—that is, 36 inches diameter. From the nature of the problem we know that the required pulley will be smaller than 36 inches, and consequently we place for the second term the smaller of the remaining known numbers—that is, 120. Three hundred then becomes the first number of the proportion, which stands as follows: 300 : 120 :: 36 : —. Multiplying 36 by 120 we get 4,320, which divided by 300 equals 14.4, which, neglecting the slip or creep of the belt and allowance for its thickness, is the size of pulley required to drive the shaft at the specified speed. Taking another case, we will suppose we have a shaft running 120 revolutions and a pulley on it 30 inches in diameter. From this pulley a belt runs to a 22-inch pulley on another shaft, and we wish to know the speed of this second shaft. Here, since speed or revolutions per minute is what we want to know, we place the known figure of the same denomination for the third term,

and this is obviously 120. Then, by the nature of the problem, we know that the answer will be greater than 120, and consequently we place the greater of the remaining numbers for the second term and the remaining number for the first term, and the proportion therefore stands as follows: 22 : 30 :: 120 : —, and $30 \times 120 = 3{,}600 \div 22 = 163.2$ revolutions. This old-fashioned rule of three is perhaps more generally useful, and useful in a greater variety of ways in machine shop calculations than any other that could be mentioned, and every machinist should be thoroughly familiar with it.

470. Q.—Kindly explain to me how to line a pulley that is at right angles with another. For instance, the driving pulley is 6 feet in diameter, and that to be driven is 28 inches; the former is placed on a horizontal shaft and the latter on a vertical shaft. I have not succeeded in placing the pulleys on the shafts so that the belt will stay on while running.

A.—The single and sufficient condition that the belt may run properly is this: The point at which the belt is delivered from each pulley must be in the middle plane of the other pulley. If the belt runs in the direction as indicated in Fig. 2, then the point at which the belt is delivered from the pulley A is at h_2; this point is represented by h in Fig. 1; it must lie in the middle plane $c\ d$ of the pulley A and in the middle plane $e\ f$ of the pulley B, and in a line of their intersection tangent to both pulleys. It is of importance to have the pulleys far enough apart so as to give an easy twist to the belt, and in practice the pulleys may need a little adjustment on their shafts so as to make the belt run properly. With the position of pulleys as here shown the belt will run only in the direction as indicated by the arrows.

471. Q.—How can I determine the proportions of the hubs of pulleys for transmitting power?

A.—The rule generally adopted is to make the diameter of the hub twice the diameter, or nearly so, of the shaft to which the pulley is keyed. The length of the hub is twice the diameter of the shaft plus the thickness of the arms at the center. The hub and arms should be central with the face.

472. Q.—If in transmitting power from A to B we are not tied as to distance between centers, what determines the size of the driving wheel if one wheel is larger than the other?

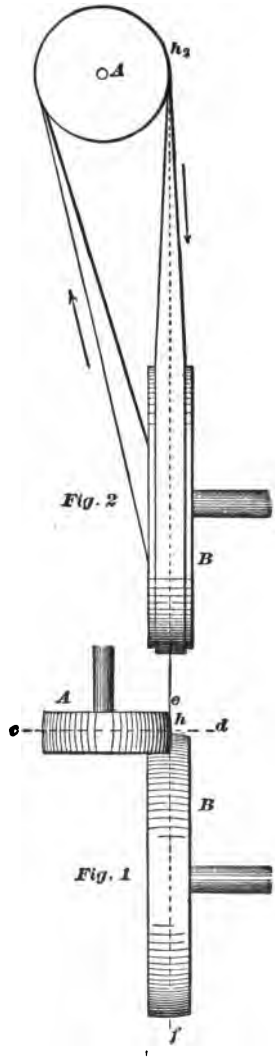


Fig. 2

Fig. 1

A.—The pitch diameters, or, rather, the numbers of the teeth of the two gears, will be inversely as the numbers of revolutions. The actual sizes of the gears will be determined as in the case of pulleys, by the amount of power to be transmitted.

473. Q.—Please give me a rule or formula by which I can get the horse-power which can be transmitted by shafting of different sizes at different speeds. For example, how much power will be transmitted by a shaft 7/8 inch diameter, running at 1,800 revolutions per minute?

A.—For turned shafting under ordinary conditions the formula is:

$$H = \frac{D^3 \times R}{90}$$

where H = horse-power, D = diameter of shaft, and R = number of revolutions per minute. This means simply that the cube of the diameter of the shaft multiplied by the number of turns per minute and that product divided by 90 gives the horse-power. By this rule the capacity of the shaft mentioned would be computed in the following manner: The cube of 7/8, or .875, = .67; this multiplied by 1,800 = 1.206, which divided by 90 = 13.4 horse-power, and the shaft will transmit at that speed from 12 to 14 horse-power. The formula would, of course, be modified for steel shafting, cold-rolled shafting, or for short lengths simply transmitting power.

474. Q.—How can I find the diameter of shafting, the horse-power and speed being known?

A.—Authorities differ greatly in regard to the size of shafts. The diameter is based upon the torsional strength of the shaft; that is to say, on its resistance to breaking by twisting, and this strength is proportional to the cube of the diameter of the shaft. Considerable allowance must be made for accidental strains, such as the winding of belts, sudden resistances by clutch motion, etc. The following formula is for line shafting from which power is taken at intervals; bearings 8 feet apart. Let D denote the diameter of the shaft in inches, R revolutions per minute and H horse-power. Then, for iron shafting we have:

$$D = \sqrt[3]{\frac{90\,H}{R}} \qquad (1)$$

which interpreted is: Multiply the horse-power by a constant of 90; divide this product by the revolutions per minute, and ex-

tract the cube root from the quotient; the result will be the diameter of the shaft in inches. For head shafts supported by bearings close to each side of the main pulley or gear, so as to wholly guard against the transverse strain, the following formula will give an ample margin of strength:

$$D = \sqrt[3]{\frac{125\,H}{R}} \qquad (2)$$

The only difference in these formulas is in the constant employed. For line shafts of steel or cold rolled iron a constant of 50 may be used in formula (1) and 75 in formula (2).

475. Q.—In computing the torsion of a line shaft with bearings at the ordinary distances apart, does the length of the shaft make any difference; that is, from where the power is applied to where it is taken off?

A.—Shafts may be strong enough to resist twisting, but they may not have the required stiffness; that is to say, the angle of torsion may be too great for the work the shaft has to perform. In such cases it is necessary to choose a permissible angle of torsion. But this angle depends upon the length of the shaft. Hence we may say that when the strength only of the shaft is to be computed we do not take its length into account, but when the stiffness is to be computed the length of the shaft cannot be neglected.

476. Q.—What are the standard sizes of shafting? I mean what should be the size of a shaft turned from a 2-inch bar?

A.—The standard size of shafting turned from bars is 1-16 inch less in diameter than that of the bar. The above does not include cold-rolled iron, as this is rolled to size, and is not turned.

477. Q.—I have a case of power transmission like this: The first shaft from a water wheel runs at 100 turns per minute. On this is a 72-inch pulley with a 16-inch belt driving a 48-inch pulley on a 3-inch shaft, 60 feet long; then a 72-inch pulley on the other end of this shaft drives a 36-inch pulley on a countershaft, and from this another 36-inch pulley drives to an 18-inch pulley on a saw arbor carrying a heavy circular saw. The power supposed to be used is about 60 horse-power. We have trouble with the 3-inch line shaft, which seems to be too light; the couplings have given out two or three times already. What is it best to do about it?

A.—The line shaft should have been 4 inches. The pulleys may be changed so as to speed it up and relieve it of some of the strain in that way. Let the 72-inch pulley drive a 36-inch, and then a 54-inch pulley on the other end of it drive to the 36-inch pulley on the countershaft. The line shaft will thus be speeded up to 200 revolutions instead of 150, and the speed of the saw will be the same as before.

478. Q.—At what ratio does the power consumption increase as the speed of a revolving pulley increases?

A.—With the same pull of belt the transmission of power will be directly as the speed. At double the number of revolutions per minute the power will be double.

479. Q.—I would like to know some rule for finding the horse-power of a machine. I mean some simple rule that will not require a knowledge beyond ordinary arithmetic. If there is one, please let me know it through your columns.

A.—We suppose you refer to the power required to drive machines. There is no simple rule for this purpose. The power required to drive machines can frequently be estimated by the driving belt, and the speed and diameter of the pulleys. If the pulleys are of equal diameters the power which a single belt can transmit is found by the following formula:

$$H = \frac{D \times R \times W}{2{,}750},$$

in which H = horse-power, D = diameter of the pulleys in inches, R = revolutions per minute, W = width of belt in inches. For double belts:

$$H = \frac{D \times R \times D}{1{,}925}.$$

If the pulleys are of unequal diameters the above rules should be slightly modified by using the following divisors in place of those given above. When the arc of contact of the smaller pulley is

	For Single Belts.	For Double Belts.
One-fourth of the circumference, use.....	6,080	4,250
Five-sixteenths of the circumference, use..	4,730	3,310
One-third of the circumference, use.....	4.400	3.080
Three-eighths of the circumference, use....	3,850	2,700
Five-twelfths of the circumference, use...	3,410	2,390
Seven-sixteenths of the circumference, use.	3,220	2,250

480. Q.—I wish to put in our factory a fan to run about 1,000 revolutions per minute. The engine has a 6-foot band wheel which makes 75 revolutions. The fan has a 10-inch pulley. Would it be better to use one or two countershafts, and how fast should they run?

A.—Considering the slow speed of the 6-foot wheel, we are of the opinion that it would be better to use two shafts between engine and blower. You might arrange pulleys as follows: Belt from 6-foot pulley to 3-foot pulley on first counter; from 4-foot pulley on first counter to 2-foot on second counter; 3-foot pulley on second counter to 10-inch pulley on fan.

481. Q.—I have a pulley 3 feet in diameter on the line shaft and one 2 feet in diameter on a machine. The machine is stalled by heavy work. Can I make it go by reducing the size of the pulley on the line shaft, thus slowing the machine and reducing the horsepower required?

A.—Reducing the size of the pulley on line shaft will speed the machine slower, but will also reduce the belt speed, so that the only gain in driving the machine at all would be from the fact that the driving would be a little stronger by having the two pulleys of the same size. This could probably be more satisfactorily accomplished by increasing the size of the pulley on the machine. By increasing the size of both pulleys in the same proportion you would drive stronger at the present speed, because you would then increase the belt speed. This would keep the machine speed as at present.

482. Q.—Are the rules used for determining the speeds and sizes of pulleys applicable to friction gears?

A.—So far as the relative speeds are concerned the rules are the same; but the friction gears will carry only about one-half the power of belted pulleys of the same width, size and speed—the pulleys being made of paper and iron in the usual way.

483. Q.—How can I calculate in plain figures the sizes of pulleys to put on shafts to get a different speed from the main shaft? I must confess that I am a beginner at this part of the business, so that if you could get right down to the first and bottom principles it would help me to start right. I can do simple arithmetic, but algebra is Greek and geometry is Hottentot.

A.—We will do our best to get our correspondent in on the

ground floor. If we have two shafts, one being the driver and the other the driven shaft, and if the pulleys on each are of the same diameter, with a belt connecting them, then the speeds of the two shafts will be the same. If the pulley on one shaft is one-half the diameter of the pulley on the other shaft, then the speed of the shaft with the smaller pulley will be double that of the shaft with the larger pulley. If we have a shaft at 150 revolutions, with a 60-inch pulley driving a 30-inch pulley on another shaft, then the speed of the other shaft will be 300 revolutions. Here the speed of the first shaft multiplied by its pulley diameter is equal to the speed of the second shaft multiplied by its pulley diameter: $150 \times 60 = 9{,}000$; and $300 \times 30 = 9{,}000$. In all cases, no matter what may be the speeds or the diameters, they must always at least have this relation to each other. The product of the speed and pulley diameter of either shaft must always be equal to the product of the speed and pulley diameter of the other shaft. Multiply together the revolutions and the pulley diameter of one shaft and divide this by the revolutions of the other shaft if the pulley diameter is wanted, or divide the same product by the pulley diameter if the number of revolutions is wanted. With a shaft at 120 revolutions and a 48-inch pulley, what should be the diameter of a pulley on the other shaft to give 160 revolutions? $120 \times 48 \div 160 = 36$ inches. With a shaft at 140 revolutions and a 48-inch pulley, what would be the revolutions of the other shaft with a 28-inch pulley? $140 \times 48 \div 28 = 240$. In any of these computations it makes no difference which is the driver or which is the driven shaft.

484. Q.—Which is the proper position for the key-seat in a split pulley? Should it be placed in the split or at right angles with the split?

A.—The best engineers have found out that keys are not required, and do not use them. For those who insist upon the key, probably the best position for it is 45 degrees from the joint.

485. Q.—What is the standard size of key-ways?

A.—It can scarcely be said that there is a regular standard for keys, but the most popular one, and probably the most frequently used, is: Breadth of key equals one-fourth of diameter of shaft plus ⅛ inch; thickness of key equals one-eighth of diameter of shaft plus 1-16 inch; depth of key-seat in shaft equal to depth of key-seat in the hub, measured on the center line of key, not on the side of key; taper of key, ⅛ inch to the foot.

486. Q.—Which is the most economical for line shafting, grease or oil?

A.—Oil if regularly and economically fed; the grease will not flow until the bearings are heated to some extent, which is objectionable, the heating certainly indicating some loss of power by friction.

487. Q.—I have a shaft 2 7-16 inches diameter, running 70 revolutions per minute. I wish to make a steel sleeve to slip over this shaft. and to be operated by a clutch coupling, the sleeve to transmit 8 horse-power at a point 4 inches from clutch coupling. How will I compute the thickness of this sleeve so that I will have no extra weight?

A.—It will be safe to say off-hand that any weight of sleeve that will be thick enough for keying or otherwise fastening the wheel, or whatever the sleeve is to drive, will be strong enough to transmit the required horse-power. The following formula is given for the torsional strength of hollow shafts of external diameter d and internal diameter d_1:

$$Pa = .1963 \frac{d^4 - d^4_1}{d} S.$$

P is the force or resistance acting to twist the shaft and a is the distance from the axis of the shaft at which the force is applied, while S is the ultimate torsional shearing resistance of the material. This formula may be applied to the case in hand. We have to assume some of the conditions of the case. Suppose the sleeve to be 9-32 inch thick, or that the outside diameter is 3 inches. We may take 60,000 for the value of S, and that is quite low, as its value for steel ranges all the way from 50,000 to 150,000. A large factor of safety is to be used in this case, and it will be well to work it in here. Say that we take 5; then $60{,}000 \div 5 = 12{,}000$, and then we have:

$$.1363 \frac{3^4 - 2.4375^4}{3} 12{,}000 = 35{,}875.$$

This will be the value of the twisting moment $P\ a$ which the sleeve will be amply strong to carry. Suppose that this is transmitted by a pulley or gear 4 feet diameter, or 2 feet radius, and that the force or resistance which the sleeve is to stand is to be applied at the periphery. The work to be done, 8 horse-power on a shaft running at 70 revolutions per minute, will be at the periphery of the wheel: $33{,}000 \times 8 \div (70 \times 3.1416) = 1{,}200$.

This is the value of P, and as the radius of the wheel is 2 feet, $P\,a = 2{,}400$, which is considerably less than the 35,875 which was found to be very liberal for the strength of the sleeve. The formula may, of course, be used with the external diameter of the sleeve for the unknown quantity, and it will then stand like this:

$$P\,a = .1963\,\frac{x^4 - d^4_1}{x}\,S.$$

488. Q.—Relating to machinery in general, what is the ratio of increase of power required when speed is increased, say, double? For instance, suppose a planing machine with revolving cutter head is cutting a chip ¼ inch deep from boards 12 inches wide, with cutter head running 1,500 revolutions per minute; now, if it be required to run the cutter head 3,000 revolutions, how much more power will be required?

A.—We understand this question to have nothing to do with the act of acceleration up to the required increased speed, but to the maintenance of the increased speed after it is attained. If the resistance is constant the power required will be directly as the velocity, so that, within reasonable limits, double the velocity will require double the power; but the cases are few where the resistance can remain constant. In the case of the cutter head referred to, with the same chip and the same feed ratio, double the speed should require double the power, only that the removal of the chip would require more force at every instant than before. Material when being cut requires time to yield, and the same cut requires, on that account, more force at the higher speed. The friction of the air at the higher speed also increases the moment of resistance of the cutter head and belts.

489. Q.—What is the highest safe speed at which a bearing with ½-inch balls, traveling in a circle 18 inches diameter, each ball loaded to 350 pounds, could be run, or would the speed not enter into the question of safety?

A.—The Ball Bearing Company, Boston, Mass., replies as follows: "The speed of revolution hardly enters into the question of safety in a ball thrust bearing. It does, however, very materially affect the durability of the bearing, and with a load of 350 pounds per ball (which we consider excessive for ½-inch balls) on a diameter of 18 inches, we should hardly advise your

correspondent to run his bearings more than two or three hundred revolutions per minute."

490. Q.—H has a bevel paper friction gear which will not drive without slipping, and he asks the reason why. The large wheel is 40 inches diameter by 7 inches face, and makes 300 revolutions per minute. The small wheel is 18 inches diameter. The power to be carried is 35 horse-power.

A.—You are overworking the gears. The experiments of Professor Goss show that a pulley of 1 inch face, having a lineal speed of 1,100 feet per minute, will transmit a horse-power. The mean diameter of your large wheel is about 34 inches, and $\frac{34 \times 3.14 \times 7}{12 \times 1{,}100} = 17$ horse-power, nearly. Professor Goss states that this figure can be exceeded by excessive pressure, but his experiments were with parallel shafts. With bevel gears the heavy end thrust and consequent collar friction might be quite a factor. The paper wheel should be the driver.

491. Q.—What is the proper speed to run a manila rope; the distance between pulleys is 75 feet?

A.—The speed should not exceed 80 feet per second, because beyond this speed the centrifugal force reduces the working power of the rope faster than the speed increases it.

492. Q.—Will you please explain the meaning and origin of the term "running with—or against—the sun," as applied to the motion of machinery?

A.—By the term "running with the sun" as applied to machinery is meant motion in the direction of the hands of a watch when laid on a table, face upward, and "running against the sun" means motion in the opposite direction.

493. Q.—What is the best section of shafting for torsional stiffness?

A.—Circular.

494. Q.—Should a shaft be made larger in the center than at the ends for uniform torsional strength?

A.—No; provided the shaft is properly supported. If the shaft is comparatively long and supported at the ends only, the section at the center will have to be greater than at the ends, so as to resist the transverse forces due to the weight of the shaft, but not on account of the torsion alone.

495. Q.—What is the ordinary practice in making tight and loose pul-

leys; are they made crowning or left straight across the face? Which is the best practice for ordinary work?

A.—It is not usual to crown tight and loose pulleys, for the reason that it makes the belt more difficult to shift from one pulley to the other, and thus not only takes more time in shifting, but causes more wear on the belt. Where the shifting is very infrequent they may be crowned, but it is usually better to make them flat.

496. Q.—What percentage should be allowed for friction of line shafting?

A.—The friction of line shafting varies so widely and the conditions involved are so various that it is impossible to give any rule that would be of any practical value. It would not be difficult to find shafting in which the loss by friction is less than 10 per cent., while other melancholy instances are on record where the loss has been as great as 90 per cent.

497. Q.—How am I to determine what size to make a driving pulley? For instance, I have a line shaft *A*, running *a* revolutions, and want to drive shaft *B* to *b* revolutions; supposing there is nothing in the way to hinder, what determines the size of the pulley on *A*?

A.—It is always necessary to assume the size of one pulley, and then the diameter of the other will be inversely as the required speed of its shaft to that of the first shaft. The principal consideration determining this size will usually be the amount of power to be transmitted. If the power to be transmitted is large then both the diameter and width of the pulley should be larger than if the power is small. If one shaft is to run at double the speed of the other then its pulley will be only one-half the diameter, but in one case both pulleys would be larger than in the other case. Allowing 50 square feet of belt travel per minute if single, or, say, 35 square feet if double, will give a good basis from which to start in determining the size of the pulleys. Say that a shaft running 150 revolutions per minute requires a pulley to transmit 3-horse power to another shaft. This will require $50 \times 3 = 150$ square feet per minute. If we take a 3-inch belt, then the travel of the belt must be $150 \times 4 = 600$ feet per minute. As the shaft makes 150 revolutions per minute then $600 \div 150 = 4$ feet of belt travel per revolution, or 4 feet will be the circum-

ference of the pulley. If we call the circumference three times the diameter, which is near enough for this case, the diameter of the pulley will be 48 inches ÷ 3 = 16 inches. The diameter of the pulley on the other shaft will then be determined in the usual way, and it will be to the diameter of this pulley inversely as its speed is relative to that of the first shaft. If this shaft is to run double as fast as the first shaft it will require a pulley 8 inches in diameter, and in that case it might be thought best to use pulleys of larger diameter and a narrower belt. Thus 24-inch and 12-inch pulleys with a 2-inch belt would give practically the same result and would usually be preferable.

498. Q.—I wish to drive an 8-foot drum 40 turns a minute. Would a geared or direct-connected engine give the best economy?

A.—A decision between a "first motion" and geared hoisting engine requires a careful study of all the particulars of a case. Geared engines are preferable with small loads and low speeds, and first-motion engines with the reverse conditions. The geared engine runs faster than a first-motion, and a smaller cylinder does the work, the saving in engines more than offsetting the cost of the gears. As the speed of hoisting and weight of the load increase, this advantage drops off, and finally disappears. In your case we should say that, unless your load is heavy, the advantage would be on the side of the geared hoist. With equally good engines there is no difference in the steam consumed, beyond the friction of the gearing; but, practically, first-motion hoists usually have better engines, and so give better economy.

499. Q.—In the case of gears, if two spur gears of equal diameter run together on shafts *A* and *B*, and if two smaller gears were put on in place of them with an intermediate gear to connect, would there be any difference in the amount of power transmitted?

A.—There would be no difference, except that in the latter case, there would be a slightly increased loss by friction.

500. Q.—I am a blacksmith, and have some ideas of a machinist's work. I have charge of a machine shop and foundry. On account of the increase in the business we have to put in new tools. Have you a paper or a book that will assist me in finding the correct speeds of all kinds of machinery, and computing the speeds of shafting?

A.—Write to the manufacturers of the tools, for catalogues; these generally give the speed for each machine, and also the speeds for the countershafts. For computing the speed of the shafts, it is only necessary to remember that the speed of one shaft (to which we may give for the sake of distinction, the name, "countershaft"), multiplied by the diameter of its pulley, is numerically equal to the speed of the other shaft (which we may name "main shaft"), multiplied by the diameter of its pulley. It is always more convenient to express these conditions in symbols. Thus: Let s denote the number of revolutions per minute of the countershaft; d the diameter of its pulley in inches; S the number of revolutions of the main shaft, and D the diameter of its pulley in inches. We then have:

$$s \times d = S \times D.$$

From which we get the following formulas:

$$s = \frac{S \times D}{d}$$

$$d = \frac{S \times D}{s}$$

$$S = \frac{s \times d}{D}$$

$$D = \frac{s \times d}{S}$$

501. Q.—I have a chain of wrought iron, 2½ inches diameter, that I run over a wheel with five pockets into which the chain fits. The very heavy strain on the chain wears the shoulders of the pockets rapidly, tending to let the chain slip through. Would there be any objection to a cast-steel wheel? Would the steel wear more slowly than cast iron, or would it be likely to damage the chain?

A.—It would probably be well to use the cast-steel wheel. Steel gears certainly last much longer than cast-iron gears, under the same conditions. If the chain links wore, it would necessarily be slower than the wheel, as the wear would be distributed over many more links as compared with the five shoulders in the wheel. It might be well, if possible, to change ends with the chain when putting in the new wheel to get unworn bearing surfaces to begin with.

Shop Practice.

502. Q.—What rule is there for making fits to "swear by" ? For instance, in making a force fit, say, of a 6-inch shaft to press on, at eighty tons, or to fit a piston to a cylinder 40 inches diameter, or to make neat running fits?

A.—The ability to make such fits with certainty is one of the things a machinist acquires, if at all, by practice. The novice who must attempt it had better first make his fit surely tight enough and then try it, reducing the size until the fit is right. Careful calipering of the hole and shaft will then show what the fit must be in similar cases. In learning to make such fits, the best plan is, however, to get an experienced man, if possible, to do the calipering, and then before the work is put together let the learner carefully caliper hole and shaft in his own way and with his own calipers. It is, however, getting to be common to use large inside micrometer calipers for this work, and when this is done the needed allowance for various cases can soon be made a matter of record in decimals of an inch.

503. Q.—What allowance is generally made for a shrink fit on a pin 4 or 5 inches diameter, so that when the casting is heated to a degree which will show it to be just getting red it will slip on the pin, and in cooling stick to it? The castings are of the general run.

A.—No regular fixed rules for the shrinkage allowance can be given, as much depends on the quality of the metal, thickness of castings, general workmanship, etc. We believe that an allowance of .0008 inch per inch of diameter will generally give satisfactory results. Hence a pin 4 inches diameter should be made $4 \times .0008 = .0032$, or $\frac{32}{10000}$ inch larger in diameter than that of the hole in the casting.

504. Q.—What is the usual practice in measuring the depth of keyseats in pulleys and shafting? Is the depth measured at the edge of the keyseat or from the circle at the center?

A.—The usual practice is to measure the depth at the side of

the keyseat, though sometimes it is convenient to determine the corresponding depth for the middle of the keyseat measured from the periphery of the shaft, and this depth is then used in sinking milling cutters into the shaft, the measurement being made by the micrometer, with the first touching point of the milling cutter as the beginning of the measure.

505. Q.—What taper, if any, is considered best for hardened steel mandrels to take work with straight reamed holes? Should part of the mandrel be straight, or should it taper the whole length to be up to best practice?

A.—The mandrel should be slightly taper, say 1-16 inch to the foot, and a bushing with a hole of the same taper, and parallel on the outside, the exact diameter of the hole in the piece to be held, should go with it. The bushing should be slit completely through one side, and then, when the mandrel is driven in, the work will be held true and tight.

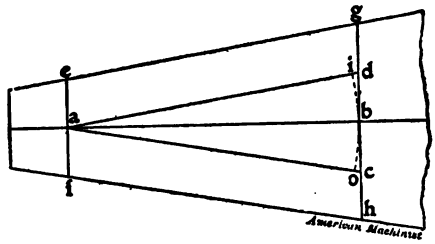
506. Q.—In turning tapers in the lathe, what is the effect if the tool is not set at the same hight as the centers?

A.—Take a piece of wood and center it in the usual way for the lathe. Set the lathe to turn the greatest taper possible, and put in a tool which can be made to cut at or near the top of the piece of wood. Arrange, if possible, so that the tool will pass over the center of the piece at about the center of its length. The sides of the piece will then be double curves, and the reason for it will be readily seen. When the cutting point of a lathe tool moves in a line parallel with the line of centers a cylinder is produced. When it moves in a line which is not parallel with the center line, but intersects it at some point, a cone or taper with straight sides is produced. When it moves in a line which is neither parallel with the center line nor intersects it at any point, neither of these forms is produced, but the work will have a curved outline. We advise trying the experiment described above, which will show in an exaggerated form just what occurs when a taper is attempted to be turned with the tool elsewhere than level with the center.

507. Q.—What is the amount of taper per foot in a reamer with one degree taper?

A.—Let the sketch represent the end of a taper reamer with the taper purposely very much exaggerated. If *a b* is one foot,

then the difference in length between *e f* and *g h* will be the taper to the foot, as commonly measured. Drawing *a d* parallel to *e g* and *a c* parallel to *f h*, and assuming the angle *d a c* to be one degree, angle *b a c* will be one-half of one degree, and *b c* will be the tangent of that angle. From a table of tangents for radius 1, we find that the tangent for one-half of one degree, or *b c*, is .008726, and the length *d c* is, therefore, 008726 × 2 = .017452. Then .017452 × 12 = .209424, which is the taper per



foot, stated as a fraction of an inch. As 3-16 inch is, in decimals, .1875, the above is evidently a trifle more than that, and the taper for one inch, or .209424 ÷ 12 = .017452.

508. Q.—Please give me a rule to find the taper on a lathe with taper attachment. For example, say, a piece is 8¾ inches long, and is tapered for 5 inches of its length. The diameter at large end of the taper is 1.282 inches, and at the small end 1.026 inches, what is the taper per foot?

A.—The length of the piece may be disregarded in computing the taper per foot, and the problem may be stated in the form of simple proportion, because the difference in diameter between the large and small ends will bear the same proportion to the length of the tapered portion as the taper per foot bears to 12 inches. Stating it thus, we have the proportion for this case, 5″ : .257″ :: 12 : .6168″, the last figure being the taper per foot. In other words, we can solve such problems by multiplying the difference in diameter between the large and small ends by 12 inches, and dividing by the length of the tapered portion of the work.

509. Q.—The statement is made that a grindstone should run "just fast enough to cause the drops of water to begin to fly." Now, how

shall I determine the exact speed at which that occurrence takes place?

A.—Turn the stone by hand until the required speed is obtained, then count the number of revolutions made per minute. With a 36-inch stone the speed is about 88 turns, or a surface velocity of 829.22 feet per minute. From this, the speed required for any size of stone may be easily computed.

510. Q.—I have a special reamer to make which is to have twelve flutes; each flute has to be deeper than the preceding one, until the seventh, which is the same depth as the first, and so on; each opposite tooth is to be the same depth, and the tops of each tooth are to be the same width. Kindly explain how to set the milling machine to cut reamer correctly.

A.—You do not say what kind of a machine you have for doing the work, but assuming that it is a universal machine, set the index for dividing twelve flutes in the ordinary manner, and move the outer pin as usual. Make a trial cut for the first flute, and then revolve the reamer half way around and make a similar trial cut. Then push in the pin that holds the plate, and move the plate four holes in the same direction as when indexing. Then index for the next flute and make a trial cut, observing the depth, to give about the right amount of "land." Again turn the reamer half way around and make a similar cut. Before indexing for the next pair of flutes, turn the plate as before two holes, and for the next pair one hole. Then for the next pair turn the plate back one hole, then two holes, and then four holes for the last cuts. The depth of the cutter must be varied to give proper width on top. The movement may be varied in amount; but the method is simply to give the reamer more than its regular movement for one-fourth a revolution, and then correspondinly less for the next fourth of a revolution, so that the teeth gradually decrease in pitch half-way around. Where there is only one pin the same result can be reached by regularly increasing and then decreasing the movement as the indexing proceeds.

511. Q.—Using the formula $D - \frac{1.299}{n}$ for the diameter of tap drill, D being the outside diameter of the srcew and n the number of threads to the inch, what proportion shall I use in tapping steel, wrought iron, cast iron, brass and other metals?

A.—We are not aware that any effort has been made to establish any rule for this. As the threads rise more or less in tapping most of the metals, and as it is usually not advisable to tap cast iron to quite a full thread, probably if the above constant is reduced a little and is made to range from 1.1 to 1.2 the resulting threads will be satisfactory. The difference in ultimate strength in tapped holes between perfectly full threads and those which are slightly incomplete at the point is small, and it is a common practice of the shops not to make full threads in holes tapped in cast iron.

512. Q.—Is it practicable to bore a 6-inch cylinder 12 feet long with a boring bar 2 15-16 inches diameter with traveling head?

A.—We think it could not be well done in a horizontal position, but if placed vertical it might be done. Use four cutters and have the cutting faces square with the bar, so that in cutting they would not have any side thrust. But why not revolve the pipe in a long lathe and use a half-round bit. The bit need not be so expensively made as those that Uncle Sam uses.

513. Q.—In the construction of engine lathe headstocks, how are the live spindle bearings lined up so that when a piece of work is clamped to the face-plate it can be bored parallel from end to end?

A.—The same method is not followed in all cases for doing this. The usual and what may be called the older method is to first bore and fit the bearings, and then plane the headstock to fit the bed, holding it upon the planer by an arbor passing through the spindle bearings. In some cases this has been assumed to bring the spindle sufficiently close to accurate alignment, but in other cases where more accurate results are wanted, an arbor carrying a sweep at its outer extremity is placed in the bearings in place of the spindle, and this is rotated from front to back and tested to see that the arm attached to said arbor moves in a plane at right angles to the shears of the lathe, and if it does not, then the V-grooves in the headstock are scraped until the alignment is correct. Another method now followed by some builders is to first plane and scrape the headstock to a fixed standard, and then bore the seats for bearings with a boring bar passing through bushings known to be in perfect alignment with the seat to which the headstock is secured in the

fixture, the boring bar being driven by a universal coupling, so as to be unaffected by any want of precise alignment between the drill press or boring machine spindle and the fixture.

514. Q.—To what depth should studs and machine screws be screwed into cast iron?

A.—Studs and machine screws, which are seldom if ever required to be taken out of the pieces into which they are screwed, should extend into the cast iron to a depth equal to about one and a half times the diameter of the studs. If the screw bolts or studs must be frequently removed, and the pieces into which they are screwed remain stationary, the screws should extend into the cast iron to a depth equal to about twice the the diameter of the screw. If the pieces into which the screw bolts are screwed have a high rate of reciprocating motion, such as locomotive pistons, the studs and screw bolts should extend into the cast iron to a depth equal to about three times their diameter. Of course these are arbitrary rules, and may have to be changed for special cases.

515. Q.—Is lime good to put on machinists' tools to prevent them from rusting; if not, what is?

A.—Lime is an excellent substance to put into a case where specimens of broken or fractured metal are kept, as it readily absorbs the dampness. Lime is also good to place in a room where finished tools or other work are stored, or are in cases for exhibition. But we would not recommend direct application to the surface of steel. We have always found a light coating of good clean sperm or lard oil equal to any emergency. If the tools are laid away they should be wrapped in oiled paper.

516. Q.—Is it possible to cut a left-hand thread with a right-hand die?

A.—It is both theoretically and practically possible to do so. A single-thread die with two rows of cutters opposite each other would cut a left-hand single thread as well as a right-hand thread, except that there would be trouble about the clearance if the cutters were anything but points or thin sheets of metal. A single-thread right-hand die with three rows of cutting teeth would cut a double left-hand thread; a die with four rows of teeth would cut a triple left-hand thread, and so on. The cutting would not, of course, be clean and neat, but the cutting teeth would at least follow each other in the proper order, and

with the spacing to produce the result mentioned. The question is rather a theoretical than a practical one. These queer threads are, however, sometimes accidentally produced and require explanation.

517. Q.—On which side of a slide for milling machine or lathe should the gib be placed?

A.—Opinions differ somewhat, if we judge from the practice of different builders. Our opinion is that it should always be placed so that the strain of the tool in cutting will bring the greatest wear on the gib. The reason for this is, that the gib is the easiest part to renew; also the gib being adjustable, the effect of unequal wear remedies itself in the adjusting.

518. Q.—What is the proper speed for milling machine cutters; also at what speed should the work be fed?

A.—Brown & Sharpe reply as follows: "The proper feed and speed for milling cuts is so much varied by the many different conditions of the work to be done, such as length and width of cut, shape of cutters, amount of stock to be removed or depth of cut, etc., etc., as also the stiffness of the machine upon which the work is done, that it is a difficult matter to give any fixed rule for the same. Good practice would seem to be: say, for wrought iron or soft steel, a surface velocity of cutter of 30 feet per minute, and a feed of from one to two hundredths of an inch to each revolution of cutter; for cast iron, surface velocity, 40 to 50 feet per minute, feed, two to three hundredths of an inch to one revolution of cutter; for bronze, say 60 to 75 feet surface velocity, feed, three to four hundredths to one revolution of cutter. But, as before remarked, these speeds and feeds may be very much changed, either increased or decreased. We have one short cut running in our works on annealed cast iron, where the mill runs 200 revolutions per minute, with a feed equal to 9¾ inches in the same time, which is equivalent to a surface velocity of 116 feet per minute, and a feed of about five one-hundredths of an inch to one revolution. The mill is 2¼ inches diameter."

519. Q.—What is the general practice in charging for work on machine repairs? Is it to add a percentage, for profit, to the cost of the job?

A.—The practice is to charge by the hour for jobbing work, charging up the stock used, but making no percentage charge.

520. Q.—What should be the circumferential speed of a milling cutter, in feet, working steel, iron, and brass?

A.—For steel from 30 to 75 feet per minute, according to character of steel and of cut being taken. For iron about the same. For brass from 100 to 300 feet. No definite rules can be given in such matters which will be universally applicable.

521. Q.—What is the proper speed for planing such metals on a planer?

A.—Planers are usually speeded at 20 to 25 feet per minute, but if a planer were to be used exclusively on brass it might be speeded as high as the machine itself would stand.

522. Q.—By what simple process can I know that a lathe is set straight?

A.—The simplest process is to take a trial cut and test the work with calipers.

523. Q.—How have I to set my center-rest when I wish to do a good job?

A.—Set it so as to be exactly in line with the centers. One way of doing so is to turn a place on the work where the rest is to be applied. Then put on the rest and adjust it so that the tail center will be in line with the center made in the end of the work.

524. Q.—What is the correct rule for finding the exact size to bore a hole, and have it tap out a full thread?

A.—We assume that you wish to know the diameter of the hole in a nut, which, after it is tapped, will have a full American standard thread. Divide 1.299 by the number of threads per inch, and subtract the quotient from the outside diameter of the bolt; the remainder will be the diameter of the hole. This rule is based on the following principle: The diameter of the hole should be equal to the outside diameter of bolt or thread, diminished by twice the depth of the thread. Now, since the depth of the thread is always equal to .6495, multiplied by the pitch, it follows that in order to obtain the diameter of the hole we must diminish the outer diameter of the thread by $.6495 \times 2 \times$ pitch $= 1.299 \times$ pitch. But the pitch is obtained by dividing one inch by the number of threads per inch; hence the outside diameter must be diminished by 1.299, divided by the number of threads. If we put this rule in the shape of a formula, we have:

$$\text{Diam. of hole} = \text{diam. of bolt} - \frac{1.299}{\text{Number of threads per inch}}$$

Example: What should be the diameter of the hole in a nut for 2½ bolt ¼ of an inch pitch?

$$2\tfrac{1}{2} - \frac{1.299}{4} = 2.176 \text{ inches} = \text{diam. of hole,}$$

or, say 2 3-16 inches, nearly.

525. Q.—I wish to use a circular saw on sheet brass, from 1-16 inch to ¼ inch in thickness. At what speed should it be run?

A.—The velocity of the saw at its periphery should be from 1,500 to 2,000 feet per minute.

526. Q.—In grinding internal and external cylindrical gages, which one is ground first, as I understand that to grind both to the exact size would not permit the ring gage to pass over the plug and that the external gage must be a little over size or the internal one a little under size. Which is correct?

A.—Either gage may be ground first and fitted to the other one, and we do not know that it makes any material difference in which order they are fitted, though it is usual to make the plug gage first because it is considered to represent the precise nominal diameter, any variation for fitting necessary being made in the ring. Perhaps the chief reason for this is that we possess far better facilities for measuring plug gages than for measuring ring gages. Such gages, if made with any great refinement, are finished by lapping, and when thus made are very true, round and smooth and can be put together notwithstanding that they are so nearly the same size that ordinary methods of measurement can detect no difference between them, though as a matter of fact the plug gage must of course be slightly smaller than the ring gage, in order to get them together. Regarding this matter Geo. M. Bond, who is in charge of the gage department of the Pratt & Whitney Company says: "The diameter of the gage has considerable to do with the difference between the size of the plug and ring for a gage fit such as you mention. A ring gage 1¼ inches diameter would have to be about 1-25,000 inch larger in diameter than the standard plug, the plug in *every case* being considered the reference or basis. As the size of the gage diminishes, this difference between the diameter of the plug and ring would evidently decrease, owing to the diminished area of surface contact. This depends, of course, on the gage being perfectly round, hard and smoth, or as near these conditions as is possible to make them in the highest state of the art."

527. Q.—What is the best material to polish aluminum, and what is a good lacquer to apply to it?

A.—Aluminum can be polished on a buffing wheel with rouge, the same as brass, and for polishing any considerable quantity of sheet, this, of course, is the most economical way. In the absence of any special aluminum polish, several of which are now sold, ordinary cold brass polish will be found to answer, provided it is ground fine enough. A polish which bears the name of the "Acme" is good for this purpose and consists of stearic acid, one part; fullers earth, one part; rottenstone, six parts. The whole should be mixed and ground fine. Use a fine white rouge or tripoli and a chamois skin buff, although it is often polished with an ordinary rag buff. Aluminum is seldom lacquered, but the ordinary lacquers answer for it.

528. Q.—What is the proper speed in feet per minute for turning, planing and milling cast steel, wrought iron, cast iron, and brass?

A.—Much depends upon the character of the cuts taken, and we think it is almost useless to attempt to lay down any fixed rules for this. But for average conditions we should say that cast steel could be most advantageously turned and planed at 18 feet per minute, and milled at 40 feet, when using plenty of good oil. Machinery steel, about the same, and also about the same for wrought iron in milling, but somewhat faster for turning and planing, say about 20 feet. Cast iron can be planed and turned at 20 feet, and milled at 50. Brass can be turned at 60 and milled at 85. It is to be understood, however, that these are only average figures, and that practice varies widely from them, according to the quality of the metal worked, the character of the cuts taken, the degree of accuracy and finish desired. quality of the tool steel used, and the character of the machines in use. Experience and good judgment are the only reliable guides.

529. Q.—If a lathe will face the face-plate off straight, does that prove that the spindle is true both ways with the bed of the lathe?

A.—No, it does not prove that the spindle is in line with the bed either way. It simply proves that the spindle is at right angles to the cross-slide. Both may be out of square with the bed and the spindle may be out of line vertically.

530. Q.—I wish to bore a hole 1¼ inches diameter, in a solid piece of

cast iron 7 inches deep. I use three drills, the last one being a turned flat drill 1-64 inch smaller than the reamer. I use one reamer having 12 flutes 6¼ inches long, slightly tapered for one inch at the end. I enter the reamer at slow speed in the lathe and force it in two inches, after which I ream it the balance of the way in the vise, for the reason that starting it in the lathe will spoil the reamer. Which is preferable if either, and why will it spoil a reamer to do as I did?

A.—We infer from your description that the reamer used was a hand reamer, and in the first place 1-64 inch is altogether too much to ream out with it, .005 inch being plenty. It will not injure a hand reamer to be used in the lathe, provided the speed is very slow, the cut very light, and it is not allowed to leave the back center and get caught; but the trouble with using such reamers in the lathe is that a failure in one or more of these points is liable to occur, and if it does the reamer is very likely to be ruined.

531. Q.—What is the best material with which to daily wipe the bright parts of machine tools to prevent rusting and discoloration?

A.—Discoloration of bright parts often results from the use of a lubricating oil which either contains some acid that corrodes, or, by evaporation, leaves upon the surface a brown or yellow coating. Avoid such oils. A good plan is to take pains to keep the bright parts somewhat oily, where the use of the machine does not have this effect, and, if necessary, rub them occasionally with vaseline, which can be applied by a piece of waste. It is usually difficult, however, to entirely prevent discoloration, and there must usually be some scouring with emery cloth if its entire prevention is important.

532. Q.—What is the diameter at large and small ends of standard steel mandrels 1 inch nominal size? Are these mandrels left hard, or are they tempered, and if so, to what color?

A.—We find such arbors to be tapered usually about .01 inch in 12 inches, and standard size about midway of their length, though sometimes nearer the small end. They are usually made of crucible machinery steel, or a lower grade of tool steel, and are left hard, *i. e.*, the temper is not drawn.

533. Q.—Which way should an engine lathe set in a shop; that is, should the workman face the window or not?

A.—This is a matter of opinion. Our opinion is that the light should come to the lathe over the shoulder of the workman; in other words, that he should stand with his back to the window.

534. Q.—What is the meaning of the term lap, used in correcting hardened pieces of steel that have been sprung in hardening, and how is the process perfomed?

A.—A lap is anything which will hold grinding material, which may be emery, diamond dust or other abrasive. For instance, a flat piece of cast iron becomes a lap when the flour of emery and oil are placed on it, and a piece of hardened steel that has been sprung and is to be ground straight again is rubbed over it. For grinding out holes, laps are made cylindrical, of lead, wood, cast iron, or steel, and run in a lathe. For solid cylindrical work the lap becomes simply a hole which is made in any of these metals, and it usually has some means of closing it on the work as the grinding proceeds.

535. Q.—I have to finish by lapping a good many small holes in steel varying from ½ to 1-16 inch in diameter. I use a copper lap and fine emery, but find that I cannot get the exact size all through the hole. The ends are larger than the middle, and I would like to know how the trouble may be avoided.

A.—This trouble sometimes cannot be entirely avoided, though it is lessened by arranging to do as little lapping as possible. That is, to have the hole originally, by grinding, as near the finished size as may be. You will find, also, that a cast-iron lap is better than copper and will be likely to cause less enlargement at the ends. Sometimes, however, the difficulty cannot be otherwise overcome, and it is then the practice to leave a thin ring of the steel around the edge of the hole to be lapped at the same time and to be removed by the grinding afterwards, thus removing that part which has been unavoidably enlarged in the lapping operation.

536. Q.—What is the best method of cleaning and drying screws, after they have been case hardened, to prevent their rusting?

A.—The practice is to dry the screws in a sieve over a fire, then put them in oil, take them out and drain them by placing in a sieve, then dry them in sawdust, either by hand or by tumbling them in a tumbler.

537. Q.—A man is cutting a keyway in a crank on a slotting machine; he claims that, by setting the crank so that the corners of a square-nose tool touch the bore of the crank at the two sides of the keyway as it is laid off, that the keyway will be true whether the face of the tool is at right angles to the line of feed or not. I say that the sides of the keyway will not be square with the bottom if the tool is ground so that the cutting face is not square with the feed screw and the job is set in the way he says. Which is right?

A.—You are right.

538. Q.—What is commonly used for lubricating the slide rests, etc., of lathes?

A.—Lard oil, or any good mineral oil.

539. Q.—I had occasion recently to put a brass lining in a pump cylinder 10 x 18 inches. The lining was 3/8 inch thick after being turned to size. I concluded to heat the cylinder and secure the lining by shrinkage. When the cylinder had been heated, the lining dropped in very nicely, and then got tight, but after all was cooled the lining was found to be 1-64 inch loose. Can you explain it?

A.—Our guess is that the body of the cylinder, being very much heavier than the brass lining, contained sufficient heat to heat the lining to a pretty high temperature before it was itself cooled very much. This heat in the lining caused it to enlarge, and the co-efficient of expansion for brass being greater than that of iron, it expanded rapidly, and, by the pressure thus brought upon it while hot, it was to a certain extent crushed or compressed. Then, as the cooling process proceeded, the brass shrinking more than the iron by reason of its greater co-efficient of expansion, the shrinkage in the former continued until it was as much smaller than its former size as was due to the crushing effect referred to.

540. Q.—How are the divisions on a universal dividing head found? Supposing a head to have a worm of 4 threads per inch, and the worm wheel to have 40 teeth; how would you find what circle of holes to use, or number of holes to skip? Please give an example of how it is computed, taking an uneven number, such as 73, and an even number, say 72.

A.—We need pay no atention in this problem, nor in any

similar one, to the number of threads per inch on the worm. If the worm wheel has 40 teeth and the worm has a single thread, then the ratio is 1 to 40. This means that the worm wheel is rotated 1-40 of a revolution for each complete revolution of the worm or index pin, and to revolve it any given fraction of a revolution, we need only give the worm such portion of a revolution as is proportionate to the given fraction, as 1 turn is to 1-40 of a turn. Thus, taking the first example, we see that the required fraction of a revolution is to 1-73 as 1 is to 1-40, and from this it can be solved by the ordinary rule of proportion, as given in the arithmetics. A more practical method for shop use, however, is to write a common fraction with 40 as its numerator and the required division as its denominator. This in the case assumed gives us 40-73, which is the fraction of a turn necessary to turn the index pin. In this case 73 is a prime number and the fraction cannot therefore be reduced to lower terms. This shows that the number cannot be indexed in the ordinary manner unless we have a plate with 73 holes, but it can be indexed by the compound method, which is treated fully in the Brown & Sharpe Manufacturing Company's "Treatise on the Milling Machine." The nearest possible division for this number is 73.0001, which, of course, is practically exact. It is obtained by moving the index 2 42-43 revolutions, and then moving the plate 3-49 of a revolution in the same direction, for each cut, going six times around the work to complete it. Indexing 72 is much simpler. Here we have the fraction 40-72, which reduces to 20-36 or 10-18 or 5-9. This means that the fraction of a turn required is 40-72, and that 20-36 or 10-18 or 5-9 are any of them the same thing, and that by moving the index pin 40 holes in a 72 circle, or 20 holes in a 36 circle, or 10 holes in an 18 circle, or 5 holes in a 9 circle, we shall index 72.

541. Q.—Suppose we take a pulley of any diameter, and, say, 3-inch bore, and balance it upon a 1½-inch shaft; will that pulley be balanced as accurately as if it was balanced on a 3-inch shaft?

A.—A pulley cannot be balanced as accurately upon a shaft that is smaller than the hole.

542. Q.—Wishing to use a grinding attachment on one of my lathes to do internal grinding (the attachment to be fastened to the tool-post and the work to the face-plate), should the work and

the wheel run in the same or in opposite directions, and at about what speed?

A.—We should run the work and the wheel in opposite directions; and about as good a rule for approximate speeds of the work as can be given would be, probably, to run it at about the speed you would run the same sized work if you were turning it in the lathe. In a general way it may be said that work may usually be run somewhat faster than this, and you will find by experience the cases in which this may be appropriately done. One important consideration in doing such work in the lathe is, to either perfectly balance the spindle, or run the lathe slowly enough so that the lack of balance does not affect the accuracy of the work.

543. Q.—What solution is best for washing the grease from nipples which have been cut with lard oil?

A.—The solution of hot sal-soda is quite generally used for this purpose, and is usually satisfactory where it is in a kettle provided with means for keeping it hot by steam, and the articles are placed in a perforated vessel, which allows of their being soused about in the solution.

544. Q.—What is the best size for gears, and a speed for a tapping machine which I am making? Sizes of taps ¾ inch, 1 inch and 1¼-inch pipe tap.

A.—Ordinarily, a ¾-inch pipe tap would be run at about 90 revolutions a minute; 1 inch, 60 revolutions; 1¼ inches, 45 revolutions; 1½ inches, 30 revolutions; 2 inches, 20 revolutions per minute.

545. Q.—What is the best method of making a face-plate for a lathe chuck, should it be first bored out, threaded to fit the lathe and then turned to fit the chuck, or should it be first roughed out, then fitted to the chuck and then finished while in the chuck, the jaws of the chuck being at the same time tightened upon a true piece of work in the lathe?

A.—We think the latter method is very much preferable. The main advantage is that the thread is by this method cut and the end of the hub faced, while the working faces of the chuck jaws are also necessarily true, and at the same time strained up as they will be when the chuck is afterwards used.

546 Q.—Is it considered good practice to polish or grind such

work as wrought iron or steel shafting either with emery in the lathe or in the universal grinder, with or without oil or water? Is there the same trouble with brass and cast iron? Is there any way to avoid such results, or are they imaginary?

A.—It should be scarcely necessary for any constant reader of the "American Machinist" to ask such questions. It is not only good practice, but the best practice to finish journal surfaces upon the universal grinder, and preferably with water, never with oil. Cast iron may be ground as well as steel. Close iron should be used, and no blow-holes allowed. Brass is not so generally ground, and generally does not require it, and would not be improved by it.

547. Q.—What is a proper lubricant for use in lathes, milling machines, etc., which will not rust the work?

A.—For heavy work on steel, such as cutting screws, good lard oil should be used, and will well repay its cost over other lubricants. For much other work, water with sal-soda dissolved in it is used. If sufficient soda is used, it will not rust the work.

548. Q.—A friend of mine claims that in computing the cutting speed of lathe work it is proper to add the rough diameter and the finished diameter together, divide them by 2, and consider that to be the diameter upon which to base calculations of speed. Is this right?

A.—The rule as given is wrong, and the diameter of the work should always be taken in the rough condition, that is, before the tool goes over it. To see the absurdity of the rule it is only necessary to consider that if we are turning a shaft of a given size and are taking a very heavy cut from it, the rule would call for a higher speed than would be the case if we were taking a light cut, simply because with the heavier cut the mean diameter between the rough and the finished size would be less.

549. Q.—Please give me a rule for computing the change gears on milling machines for cutting spirals.

A.—Select at random all the gears that are drivers, and all the driven ones except one. Consider the wheel on the screw as the first driver. Multiply all the drivers together, and this product by the lead of the screw (number of threads per inch), and by the pitch you wish to cut in inches. Divide this by the product of the selected driven gear and the number of teeth in the

worm wheel; the quotient will be the number of teeth in the remaining driven gear. Or, if you prefer, you may select all the driven gears and all the drivers except one, in which case multiply the driven gears and the teeth of the worm wheel together, and divide this product by the product of the number of teeth in the selected driver, by the number of threads per inch in the screw, and by the pitch of the spiral to be cut, in inches. These rules may be stated thus:

$$d = \frac{D D_1 S P}{d_1 W}, \text{ or,}$$

$$D = \frac{d d_1 W}{D_1 S P}$$

in which

S = threads per inch to screw,
W = number of teeth in worm wheel,
P = pitch of spiral to be cut in inches,
D = number of teeth of first driver,
D_1 = number of teeth of second driver,
d = number of teeth of first driver,
d_1 = number of teeth of second driver.

550. Q.—Please also give a rule for obtaining the number of turns and holes to move the index pin to obtain a given division.

A.—Divide the number of teeth in the worm wheel by the number of divisions you wish to cut; the quotient will be the number of turns of the index pin necessary to be made. If this is a whole number any plate will do, but if is a fractional or a mixed number, first reduce the fraction to its lowest terms, then a circle must be selected which is equal to or a multiple of the denominator of that fraction. Then divide the number of holes in the circle by the denominator of the fraction, and multiply the quotient by the numerator. The product will be the number of holes required. For instance, suppose the worm wheel contains 40 teeth, and it is desired to cut 18 divisions. Then dividing 40 by 18 we get 2 4-18, which shows that the pin must make two turns and four-eighteenths of a turn for each division; four-eighteenths reduced to its lowest terms is two-ninths; and we may take a circle of 18 holes (or we might use 27 or 36, because all these are multiples of 9) and get 2; multiplying this by 2 we get 4, and we must, therefore, turn the pin two turns and four

holes. If we had chosen the 36 circle, then we would have had two turns and eight holes, because $36 \div 9 = 4$, and $4 \times 2 = 8$.

551. Q.—Will you please tell through your columns how I can cut a groove in a piece of tool steel 2 5-8 inches diameter, the groove to be 5/8 inch deep and 5-64 inch wide at the top, tapering to 1-16 at the bottom, the bottom being round or semi-circular?

A.—We must assume first of all that the steel is thoroughly annealed. Then it should be possible to cut in a parallel groove 1-16 inch wide and 19-32 inch deep with a carefully made and adjusted square-nosed tool. The clearance should be slight on the tool, the end should be perfectly square, it should be set in the rest with a square, so that it would be true both vertically and horizontally; it should not be any longer than just enough to reach in to the proper depth, and only thin but good lard oil should be used. No mineral oil is to be trusted for a moment in a case like this. When the groove is cut in to the proper depth the end of the same tool may be rounded and used to round the bottom. Then the more difficult job of tapering out the sides is to be done. Of course, no tool so thin would be able to stand a cut of nearly 5/8 inch on each side of it all at once. A gage for grinding a taper tool could be made corresponding to the taper groove. If no file could be found thin enough to go into the slot, the gage could be made of two separate thin strips of metal, clamped to the required relative position by laying a piece on each side of them and clamping the whole together. A taper tool could now be ground thick enough to turn out the taper groove to about 1/8 inch deep and to the full width required. Then the tool could be ground thinner by the gage and the groove tapered out an eighth of an inch deeper, and so on until it was finished. We believe it to be possible to do the job in this way with sufficient care and patience. If there were several to do, it would be proper to think of the milling machine. The piece could be mounted upon the milling centers placed crosswise and then, slowly revolving it, a plain groove could be cut with a slitting saw, and the groove could be finished to the required shape with a revolving file specially made for the work. By setting a compound rest to the proper angle the sides of the groove might be brought to the required shape, one at a time, but delicate and excellent tools would be required.

552. Q.—What is the standard hight and width of a carpenters' or machinists' work bench, and of what material and thickness is the top in general practice?

A.—The standard hight of machine shop work benches is 2 feet 10 inches, and we believe carpenters' benches are about the same. The top may be of any hard wood, oak being one of the best. The plank in front should be not less than 2 inches thick, and 3 inches is better. At the back of the bench the covering may be lighter. Planed cast-iron plates are now being used to some extent for tops of machinists' benches.

553. Q.—Can a propeller which is a taper fit on a shaft, held in place by two keys set at 90 degrees from each other, be drawn off, the keys remaining fixed in the shaft?

A.—We understand in this case that, as usual, the sides of the two keys are planes parallel to the axis of the shaft, then the sides of the keys will not interfere with the removal of the wheel. The draft of the key will not interfere with the removal unless its taper is greater than one-half of the taper of the shaft, or unless the distance of the outer end of the key from the center of the shaft is greater than the distance of the inner end from the center.

554. Q.—In cutting key-seats in shafts or in wheel hubs, is it proper to measure the depth at the side of the key-seat or in the middle?

A.—It is largely a matter of taste. We would measure the depth at the sides; that is the most convenient way, and is also undoubtedly the most common practice.

555. Q.—What is the proper method in backing off reamers after being tempered? Some claim that the reamer should be revolved backwards while the emery wheel runs the other way, while others claim that the fluted reamer should be held with a ratchet, and slid to and fro while the wheel is in motion.

A.—It is not so easy to say what is the proper and absolutely correct way of doing a thing as to say what is the usual and accepted practice. Reamers are ground one tooth at a time, the face of the tooth resting against a thin spring rest, and the reamer, mounted on centers, being moved back and forth longitudinally before the edge of the revolving wheel.

556. Q.—How many pounds of pressure will be required to punch a 1-inch square hole through iron 1 inch thick, both hot and cold?

A.—The pressure will depend on the quality of the iron; at ordinary temperature a pressure of about 100 tons (2,000 pounds per ton) will be required to punch a hole 1 inch square through ordinary iron 1 inch thick. Iron at about red heat will require a pressure of 25 to 50 per cent. less than the above, depending on the quality and temperature of the iron.

557. Q.—I have read in the press of the country on different occasions that a polished steel disk 6 inches diameter and 1 inch face, running at a speed of 6,000 revolutions per minute, will cut through any kind of metal. If such is the case I would like to know if a larger or smaller disk could not be used with like results; also who is the manufacturer of the machine?

A.—Disks are frequently used for cutting metals, but we have not seen a disk 1 inch thick used for that purpose. For sawing any section of iron while cold, the cold saw is sometimes used. This consists simply of a plain soft steel or iron disk without teeth about 42 inches diameter and 3-16 inch thick. The velocity of the circumference is about 15,000 feet per minute. One of these saws will saw through an ordinary steel rail cold in about one minute. In this saw the steel or iron is ground off by the friction of the disk, and is not cut as with the teeth of an ordinary saw. Reese's fusing disk is an application of the cold saw to cutting iron or steel in the form of bars, tubes, cylinders, etc., in which the piece to be cut is made to revolve at a slower rate of speed than the saw. By this means only a small surface of the bar to be cut is presented at a time to the circumference of the saw. The saw is about the same size as the cold saw above described, and is rotated at a velocity of about 25,000 feet per minute. The heat generated by the friction of this saw against the small surface of the bar rotated against it is so great that the particles of iron or steel in the bar are actually fused, and the "sawdust" welds as it falls into a solid mass. This disk will cut either cast iron, wrought iron or steel. It will cut a bar of steel 1⅜ inch diameter in one minute, including the time of setting it in the machine, the bar being rotated about 200 turns per minute.

558. Q.—Kindly inform me how to find the power required to stove a collar 2¾ inches outside diameter and ½ inch thick on a mild steel shaft 1½ inches diameter. Also give formula for

finding the weight of drop and hight through which it has to fall to give the required blow.

A.—Pratt & Whitney Co., Hartford, Conn., reply to this as follows: "We understand by the expression 'stove a collar,' that your correspondent desires to upset a collar 2¾ inches diameter by ½ inch thick, using mild steel 1½ inches diameter under a drop hammer. The conditions of distance from end of shaft might enter into the problem, and also the time in which the work is to be done, either in one blow or several. A 600-pound drop hammer, such as we make and use for work of this kind, up to collars on 2⅝ round steel, falling 4 or 5 feet, and in several blows, does the work well. The intensity of the blow can only be expressed in terms of the weight into the distance dropped in feet, foot-pounds or foot-tons, as the case may be."

559. Q.—What is a good method for holding thin pieces of steel while being planed; say pieces 3-16 inch thick and 4 inches wide and 3 or 4 feet long?

A.—Tap the planer stakes for steel bolts, which should be fitted loosely enough in the stakes to turn easily, and should have comparatively large centers. Lay the piece to be planed on the bed, insert the stakes along each side of it, and place a round steel piece with pointed ends between each bolt and the piece to be planed, the latter having center punch marks in which one end of the round steel rests, and its opposite end resting in the bolt center, then screw up. The number of stakes required will depend on the length of the piece.

560. Q.—A claims that a plug of given size will not pass through a ring of the same size. B claims that it will. Who is right?

A.—It is not certain who is right. Sir Joseph Whitworth claimed that a plug and ring gage of precisely the same diameter, made of hardened steel, could not be put together except by the use of sufficient force to stretch the ring or compress the plug, or both. A plug and ring gage can be made to fit each other so closely that they cannot be put together by hand dry, nor with any other lubricant than that which is of very fine quality, and even then the plug must be very skillfully inserted, and very quickly withdrawn without twisting it, or it will stick so tight that it will have to be driven out. Such a plug and ring

are at least very nearly the same size, and, so far as we know, there is no way of proving by measurement that they are not precisely the same size, nor even that the ring is not slightly smaller than the plug, the metal being possibly slightly compressed or stretched as they are put together.

561. Q.—Suppose I have a piece of work held in the chuck of an ordinary lathe, and find that in boring a 2-inch hole 6 inches deep, it is 1-64 inch larger at the back, with a gradual taper from end to end. Which way has the front bearing moved, forward or backward?

A.—It has moved forward.

562. Q.—Should a punch, say 4 inches diameter, have a driving or a sliding fit in the die?

A.—The clearance of the die depends much upon the character of the work to be done. For ordinary boiler work the die is often made from 1-10 to 3-10 of the thickness of the plate larger than the diameter of the punch; and some boiler makers advocate making the punch fit the die accurately. For punching nuts, the punch fits accurately in the die. Of course a driving fit is not admissible for any kind of work.

563. Q.—I want to displace a piece of steel 2 inches by 10 inches and 1⅜ inches thick, by punching; what force will be required?

A.—We understand you to say that a hole 2x10 inches is to be punched through a steel plate 1⅜ inches thick. When a plate is punched the ultimate shearing strength of the metal must be overcome over the surface sheared. Assuming the hole to be rectanguiar in form, then the area sheared will be equal to $(2 + 10) \times 1.375 \times 2 = 33$ square inches; and if we take the ultimate shearing strength to be 70,000 per square inch, then it will require a force of $33 \times 70{,}000 = 2{,}310{,}000$ pounds, or $\frac{2{,}310{,}000}{2{,}000} = 1{,}155$ tons to punch out the piece of the size given. The ultimate shearing strength of materials is subject to wide variations dependent on the kind and quality of the material; for steel 70,000 pounds we believe to be a fair average, although the ultimate shearing strength of some qualities of steel is only 45,000 pounds per square inch, and for other qualities it is given as high as 75,000 pounds per square inch.

564. Q.—At what speed should I run a boring head for boring a hole

85 inches in diameter and 18 inches deep? There are five cutters in the head; the feed is to be 1-16 inch per one revolution. The material to be bored is cast steel.

A.—With good lubrication the speed of the cutter may be from 15 to 18 feet per minute, which is equivalent to running the bar at 0.67 to 0.8 revolution per minute.

565. Q.—Can I drive an emery wheel about 4 inches diameter by a flexible shaft fast enough for grinding the surfaces of hard dies, and can I handle the shaft running at such a high speed? The dies are of a shape which cannot be ground on an ordinary surface grinder. They are chilled and I want to grind off the high spots.

A.—You can use a flexible shaft for the above purpose and also handle it without difficulty; in fact there are machines on the market for such work, which have flexible shafts attached to them.

566. Q.—Would a patented arrangement whereby small round iron and steel could be centered, chilled and reamed for turning twice as fast as is done at present, have any value, it being comparatively inexpensive?

A.—It would, decidedly; but before you risk too much be sure that you acquaint yourself with how quickly such work is already done in the best modern shops.

567. Q.—Is it best to use oil in tapping cast iron?

A.—Yes.

568. Q.—What is the theory of the water polish on wrought iron?

A.—The water lubricates the tool, preventing tearing of the metal.

569. Q.—What is a good fluid for soldering on finished brass work? We have been using muriatic acid and zinc, but it runs through and eats off the lacquer and tarnishes the work.

A.—Clean the joints thoroughly with emery cloth, then solder with a well tinned iron, and use rosin finely powdered in place of muriatic acid. Use as little rosin as possible.

570. Q.—What is the proper amount of taper to allow in turning mandrels two feet long, which are to be used in turning pulleys and that class of work, the hubs ranging from 3 to 6 inches in length, and 3 inches in diameter? What ought the taper to be to the foot, and can you give me any general rule for the taper of mandrels?

A.—For such arbors we should give a taper of .005 inch to the foot, or .01 for the whole arbor. We do not think that a general rule for the taper of arbors is practicable. Where the work is of the best and finest quality, and kept very close to standard size, we think it is best to make the arbors of uniform size, or very nearly so, for about three-fourths of their length, and then taper them to the end. For other kinds of work we should adopt the plan recommended above, the amount of taper depending upon the character of the work, and the closeness with which it was proposed to keep to standard sizes.

571. Q.—Please give me a receipt for putting a polish on brass, something that will not deaden the bright finish left from the polishing lathe?

A.—There are several ways of cleaning and polishing brass. Good results are obtained with sweet oil and tripoli, powdered bath brick, rotten stone or red brick dust rubbed on with flannel and polished with leather. Vitriol and muriatic acid make brass and copper very bright, but they very soon tarnish and consequently require more frequent cleaning. A strong lye or roche-alum water will also improve brass. A solution of oxalic acid rubbed over tarnished brass with a cotton rag soon removes the tarnish, rendering the metal bright. The acid must be washed off with water and the brass rubbed with whiting in powder and soft leather. When acids are employed for removing the oxide from brass, the metal must be thoroughly washed afterwards, or it will tarnish in a few minutes after being exposed to the air. Sometimes the following is used: Soft soap, 2 ounces; rotten stone, 4 ounces; beat them to a paste. Or, rotten stone made into a paste with sweet oil. Or, rotten stone, 4 ounces; oxalic acid, 1 ounce; sweet oil, 1½ ounces; turpentine enough to make a paste. The first and last are best applied with a little water, the second with a little spirits of turpentine or sweet oil. All require friction with soft leather. The government method used at all the United States arsenals is claimed to be the best. The articles to be treated are dipped into a mixture of 1 part of commmon nitric acid and ½ part of sulphuric acid kept in a stone jar. After this the articles are immersed in water which should be kept close at hand, and finally rubbed in sawdust. If the brass has become

greasy it is first dipped in a strong solution of potash and soda in warm water.

572. Q.—The diameters of the steps of a cone pulley for a small lathe are 6, 4 and 2 inches. What size gears should be used to make a back-geared lathe out of it, and to decrease the speed in proportion to the steps of the cone?

A.—On the small end of the cone use a pinion 1½ inches pitch diameter, meshing with a gear 8 inches diameter, diametral pitch, 14. On the large end of cone use a wheel 7¾ inches pitch diameter, meshing with a pinion 1¾ inches diameter, diametral pitch 12.

573. Q.—What taper should be given to ordinary hardened steel lathe mandrils, and at what point should they be standard size?

A.—Practice differs somewhat on this point. A quite common plan is to give them a taper of about .005 inch, and make them standard at the middle of their length. This allows them to take work varying from .0025 inch over to .0025 inch under-standard size. We think a better plan is to make them standard and of uniform diameter for about two-thirds their length, and then taper them up to, say .005 inch at the upper end. Whether this is the best plan or not will, however, depend somewhat upon the nature of the work, and how closely the standard is to be adhered to in reaming or otherwise finishing the holes.

574. Q.—What, in figures, is a driving and a working fit? I have read that ⅜-inch rock per foot should be allowed for a driving fit and ½ inch for a working fit. What does this mean? This work is usually guessed at, but surely there must be some definite rule.

A.—There is no definite rule for determining the allowance for driving and working fits, as much depends on the kind of metal used in the shaft, thickness, and kind of metal surrounding the hole, tightness of fit required, and, above all, much depends upon the sensitiveness of touch. The term "⅜-inch rock" means the amount of movement sideways in the hole of one toe of the calipers when the other is held stationary. For driving fit, we believe this amount of rock is too much. We prefer to have the toes of the inside calipers touch the opposite walls of the hole without any rock; then match the outsides to the insides and turn the shaft so that the

toes of the outsides will touch lightly. The amount of rock for a snug-working fit depends on the diameter of the hole, and will vary from about 3-16 inch for a 3-inch hole to ¾ inch for an 18-inch hole. The outside calipers are then matched to the insides, and the shaft turned so that the outsides will lightly touch the shaft. These sizes will have to be modified when the hole is much longer than the diameter. From the above it will be seen that considerable experience is required for making the different kinds of fits, and no definite rules can be given.

575. Q.—What is the formula for calculating the clearance for punches and dies for different thicknesses and kinds of metals?

A.—We are not quite sure whether you mean the amount the die should be larger than the punch or the taper which should be given to punch and die. What is known as the "Sellers rule" requires that the diameter of the hole in the die shall be equal to diameter of punch + 1-5 thickness of plate, or $d = p + .2\ t$, in which d = diameter of die, p = diameter of punch, and t = thickness of plate. Though this is especially for boiler-plate and similar work, it is probably about right for nearly all kinds of work except such as is done on clocks and similar classes of work where accuracy with avoidance of distortion and burr are important. In such work the punch is made to just work freely within the die. As to the amount of taper given to punch and die, this depends upon the character of the work to be done, and can sometimes be decided only by an experienced man upon full knowledge of all the conditions. For boiler-plate and similar work, both punch and die may be given about one degree taper on each side. But for lighter work, especially in the softer metals, either the die or punch, and sometimes both, are made without clearance. It is a quite common practice when sheet steel is to be punched up to ⅛ inch thick, as in manufacturing operations, to give the die only a very slight clearance and the punch none at all.

576. Q.—At what speed can iron and steel be tapped and threaded?

A.—Very much depends upon the conditions in each case. For ordinary standard threads a speed of about 16 feet per minute is correct where the stock has not been previously heated by having turning cuts removed from it. If it has been thus heated, however, the speed should be somewhat slower. The

speed at which such work can be done in the screw machine is usually determined by other considerations than the possible maximum speed at which the threading tools can work, because the turning operations which consume most of the time are those which it is most desirable to have done at the proper speed, the threading operations then being done at any available speed within the maximum which can be secured without too much trouble in changing belts, etc., and in arranging for this it is much better to do the threading at a speed as slow as 5 feet per minute than to let it go as high as 20 feet, especially where the stock has been heated as mentioned above. A die generally cuts much smoother when running at a slow speed. Rough bolt work can be done at a speed as high as 20 feet per minute, with thorough lubrication; but for accurate threads it is best to keep below 16 feet per minute.

577. Q.—How are the knife edges in weighing scales put in? They appear to be cast in; but I do not understand, if that be the case, how they are kept parallel. I should think that the shrinkage of the metal would draw them out of line.

A.—The pivots are cast in. Sometimes a print is built onto the pattern and the pivot laid into the cavity in the sand in exactly the same manner as a core. In the more approved practice, however, the pattern is so constructed as to receive the pivot; so that when the pattern is rammed up, it may be drawn, leaving the pivots in their proper places in the sand. The pivot should rest on its knife edge, not on its back or end. No unusual difficulties will be met by those familiar with cores or chills. The pivot, which is slightly tapered, should be well oiled and dusted with parting sand, so as to be driven out for tempering. In softer metals, as brass or wrought iron, a hole is drilled and broached out to receive the pivot. Many levers have their knife edges milled parallel and to gage after they are cast. The final test is made, not by measuring, but by testing with sealed weights, as being quicker, more accurate and more to the point.

578. Q.—Which of the American tool-builders can plane the longest piece of work, and how long? Do they use the ordinary planer for that class of work, or have they something special?

A.—It is probably safe to say that that shop can plane the

longest piece which can get the longest piece to plane. The Pond Tool Works, for instance, did some long planing upon the gun lathes for the Watervliet Arsenal, but there can be little doubt that they could plane much longer work if required. We have not looked into the details of practice at the Pond shops, but we have seen long work planed upon a common planer by bolting another platen endwise to the regular platen of the machine, and supporting it, as it ran out over either end, upon rollers carefully set.

579. Q.—I have a number of cylinders to bore of cast iron 4 inches in diameter. What form of reamer will give the best results for these?

A.—Much will depend upon the character of the machine in which the reaming is to be done, but ordinarily the usual form of reamer would be entirely satisfactory, only it would be best usually to make the body of the reamer either of soft steel or cast iron and insert the blades in suitably formed grooves. It will be better also if the spacing of these grooves is made somewhat irregular.

580. Q.—I wish to make a surface plate about 12 by 24 inches, and would like to know the best form of plate and the method of producing a true surface.

A.—One of the difficulties to contend with is the tendency of the plate to deflect. In order to provide against this deflection, the plate is made to rest upon three bearing points which are cast to the ribs, these prevent the plate from rocking, even when it stands on an uneven surface, and whatever sag or deflection the plate may have will always be in the same direction, and may therefore be allowed for in the truing process. In some forms of plates there are two long ribs and a number of cross ribs cast to the back of the plate. The long ribs are placed as near as possible in the line of the strain between the three bearing points, and the cross ribs are placed at equal distances apart. The thickness of the ribs should be equal to that of the plate, so that changes in temperature will cause the plate to expand or contract equally. In other forms of plates, the ribs are placed lengthwise, crosswise, and diagonally, all of uniform and equal depth. To obtain an original true plate, it is necessary to make three. These are made as true

as can be done by good planers and extreme care. The best plate of the three is selected and used as a test plate, to which the remaining two are fitted; the latter are then tested with each other, and any error existing between these two is proof of a want of truth of the first or test plate. The usual method of producing a true plane surface is to finish it with a scraper.

581. Q.—I want to polish cast iron and brass surfaces turned and faced in a lathe. I want a very fine finish. What shall I use?

A.—The term "very fine finish" is rather indefinite. A good finish can be given to cast iron by using fine emery and oil applied with lead or wood grinders. For the highest degree of finish the surfaces are "stoned" and then finished with fine emery. Brass may be finished with crocus.

582. Q.—H. asks what is the best method of chucking a pattern for the rim of a sprocket or gear wheel after it has been finished on one side, so that it can be turned on the side opposite and be accurately centered?

A.—Remove the piece from the face plate on which it was turned, and if the work is quite small, cut a depression into this face plate precisely the diameter of piece just turned and ¼ inch or so deep, and press the work in firmly until it bottoms, being sure to have a tight enough fit so that the piece cannot fly out when the lathe is started up. When the work is larger and the waste of stock would be too great to thus dig into the face plate, simply screw on from 4 to 6 blocks to a circle a trifle smaller than the work to be chucked, putting two screws into each block and then turning as in the first case, except that the work ought to be pushed in somewhat further, which is accomplished by turning into the edges of the blocks clear back to the face plate. It requires great care to turn into independent blocks unless one is used to it, but it saves the face plate. On large work thus chucked screws should be put through the face plate into the piece to "make assurance doubly sure," as it is not a pleasant experience to have work "fly out" from the lathe.

583. Q.—If we have a piece of machine steel 12 inches long, held in a lathe chuck at one end and a steady rest at the other, and if we are to drill a hole through this piece with a drill 15 inches long ¼ inch diameter, will this drill have any more tendency to "run out" or drill an untrue hole if the chuck in which it is

held in the tailstock spindle be thrown out of line as much as possible by setting the tailstock over?

A.—There is no reason why it should run out under these conditions more than if in line, except what may be called accidental reasons. That is to say, if the steel to be drilled were absolutely even and uniform throughout and the feed were the same, it probably would drill as true as if in line; but since in this condition the drill would be under a strain tending to keep it to the center of the revolving work—a strain opposed by the drill, since it must be deflected in order to keep in the center, variations in hardness or uneven movements of the tail-stock screw would, we think, have more tendency to throw it out than they would have if things were in line.

584. Q.—D. sends us a blueprint of a dog for driving the spindles of bevel gears from milling-machine index heads, which we reproduce below in Fig. 1, and he desires to know if the device will

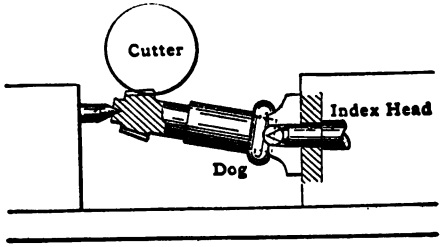


Fig. 1

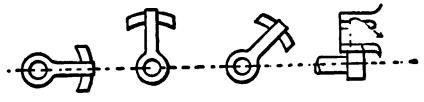


Fig. 2 Fig. 3 Fig. 4 Fig. 5

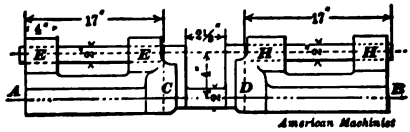
space the teeth properly. It will be seen that the round tail of the dog is in line crosswise with the end of the shaft, and that it is free to move endwise in a slot carried by the index head.

A.—The motion is correct at the point shown and at points opposite and at right angles to it, but not at other points. That this is so can be seen from Figs. 2, 3 and 4, which show the slot and tail of the dog in three positions, the spindle of the

index head being perpendicular to the paper. First imagine the pinion of Fig. 1 depressed until its shaft and the spindle of the index head are in line. In this position the index movement of the pinion will, of course, be correct, and if the replacing of the gear to the position of Fig. 1 causes movement about its axis, such movement will represent an error in the indexing of the pinion. In the position of Fig. 2, first supposing the center lines of the gear and index spindles to be in line, it is clear that raising the end of the gear spindle nearest the observer will not disturb the indexing, because the tail of the dog will simply turn in the slot. Neither will the indexing be disturbed in Fig. 3, because the tail will slide bodily in the slot. In Fig. 4, however, such lifting of the pinion shaft tends to turn the tail downward, as seen more clearly in the side view, Fig. 5, and it is obvious that if such turning downward is not permitted by the slot, the pinion must turn on its axis and the correct spacing be destroyed. At small angles the error will be very slight, of course, but it is always there, and if a considerable angle were required on very accurate work it would be inadmissible.

585. Q.—Can you point out a good method of holding crank shafts of dimensions shown in accompanying sketch steadily in lathe while crank pin is being turned?

A.—We think that if you have numbers of these shafts to turn the handiest method will be to fit up cast-iron pieces, as shown

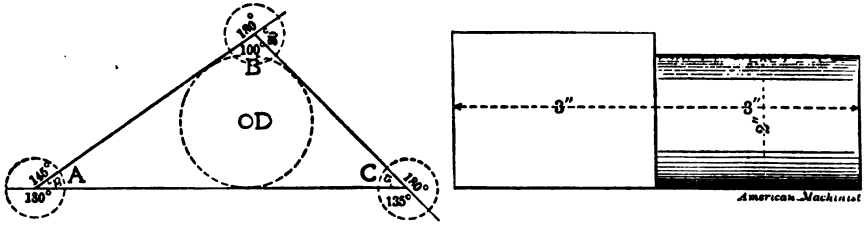


in accompanying cut. *E E, H H* are made about 4 inches diameter and bored to take the turned shaft, and the jaws *C* and *D* prevent the combination getting out of line. The jaws are tightened to the crank web by steel wedges and packing, which allows the web to be adjusted to the best position for inequalities of pin. The lathe centers are at *A* and *B*, and by having the casting bear against the web at *C* and *D* only. all bending strain on crank pin is avoided. *E E* and *H H* being bored at

the proper distance (4 inches) from the centers *A* and *B*, there is no further concern in regard to measuring for throw of crank.

586. Q.—What is the best way to get the correct angles in milling the triangular part of the piece in the sketch?

A.—We can hardly say what would be the best way, but a simple way would be like this: We assume that the piece has been centered squared up on the ends, the round part turned, and that it is mounted on the miller centers with the round part next to the dividing head and securely dogged so that it cannot turn independently in either direction. It is then set to bring one side, say *A B* right for milling, and that side is actually milled, and the platen is drawn back to make the next cut. Before cutting the next face, *B C*, the piece must be re-



volved a sufficient distance, and to do this correctly is the problem. As the angle *A B C* is 100 degrees it is evident that the piece must be turned 80 degrees to bring the side *B C* to coincide with the previous position of *A B* and ready for milling. The first proposition in geometry is: when one straight line meets another straight line the sum of the two adjacent angles equals two right angles, or 180 degrees, and 180 — 100 = 80. So, in turning from cutting the side *B C* to cut the side *C A*, the angle to be traversed will be 135 degrees, and to come again to the first position the required angular movement will be 145 degrees. The sum of these three angles will of course be 80 + 135 + 145 = 360, and these angles will be successively $\frac{80}{360}$, $\frac{135}{360}$, and $\frac{145}{360}$ of the circle. Reducing these to the least common denominator, they become $\frac{16}{72}$, $\frac{27}{72}$ and $\frac{29}{72}$, representing the portion of the complete circle to be traversed at each change. As the worm wheel in the dividing head of the machine referred

to has 40 teeth, the first movement, or from *A B* to *B C*, will require 40 × $\frac{1}{12}$ = $8\frac{8}{9}$ turns of the worm. The second movement from *B C* to *C A* will require 40 × $\frac{7}{12}$ = 15 turns, and the last movement will be 40 × $\frac{9}{12}$ = $16\frac{1}{9}$ turns, the sum of the three being, of course, $8\frac{8}{9}$ + 15 + $16\frac{1}{9}$ = 40, or the complete rotation of the worm wheel. Any circle of holes which is divisible by 9 may be used to get the fractional portion of the worm rotation.

587. Q.—Is it impracticable to punch holes of smaller diameter than the thickness of the iron that is being punched?

A.—No. With a properly made punch there is no trouble in punching iron twice as thick as the diameter of the hole, and with special appliances much more than that can be done.

588. Q.—Will you tell me the correct shape for the points of inside and outside calipers? I have some that I set alike, but the work won't go together, and I think the points must be wrong.

A.—The points should be rounded off in such a way that a part of the rounded surface will come in contact with the work of different sizes up to the full range of the calipers. Your difficulty is probably a lack of experience which will vanish with practice. It looks like a simple matter to accurately fit work by means of the calipers, but it is really something that requires a good deal of experience and something a knowledge of which can be gained in no other way than by careful practice.

589. Q.—Is it strictly proper to call any milling machine a "universal" milling machine, and if so, what constitutes a universal milling machine?

A.—We have never seen any occasion to quarrel with the term. No one objects to the statement that some fact, for instance, is universally known, yet it is not intended to convey the idea that everyone knows it. We understand that the universal milling machine is so called because it is adapted to perform such a variety of work.

590. Q.—At what speed should a smooth iron disk be run to cut iron and steel?

A.—Henry Disston & Sons, Philadelphia, reply as follows: "In common practice now, disks for cutting iron and steel (say 40 to 44 inches diameter) are run from fifty-five thousand to sixty-five thousand feet on the periphery per minute. Twenty

thousand to twenty-five thousand feet per minute used to be considered ample. Some parties in England have run them eighty thousand to eighty-five thousand feet. so we are informed."

591. Q.—What is a right-hand lathe tool? Is it a tool that is fed towards the lathe head or not?

A.—A right-hand lathe tool is one that is fed towards and cuts towards the headstock.

592. Q.—Will you tell me the easiest method of making conical springs, such as used on the valves of the Dean steam pump?

A.—Such springs can be very conveniently made by turning a conical mandrel and cutting a groove with a half-round tool, a little larger than the diameter of the wire, gearing up the lathe as for cutting a screw, making the pitch whatever you require for the spring. Then wind the spring the same as you would wind any spring in the lathe. There may be a better way than this.

593. Q.—How shall I keep from rusting some files and reamers which I want to lay away till I have use for them?

A.—Warm each one separately, oil with sperm oil, and roll up securely in a piece of wrapping paper (not newspaper).

594. Q.—Can you tell me of some handy way of setting two crank disks at exactly right angles on the same shaft? There is no quartering machine available in this case.

A.—As no sketch of the shaft is given, we can only give a general answer. As only two disks are spoken of, we assume that they are on the ends of the shaft. A line coinciding with the center of the shaft and the center of the crank should be drawn on the face of each disk, and marked by a light center punch or chisel cut if there is any possibility of losing it. One of the disks may be keyed on the shaft, leaving only the other to be set. If there is a level planer platen on which the shaft can be set, it should be leveled up on it by a surface gage, and then the line of one crank disk may be also leveled by the surface gage, and the other crank then set by means of a square, reversing the square and trying it on both sides of the line. The shaft may be set approximately level upon any suitable supports, and the disks properly set by clamping a carpenter's level upon the face of each disk, one of the levels having a

cross glass on the end for vertical reading. Then, if one of the disks is set level or horizontal and the other vertical, they must be at right angles, though the degree of accuracy attainable in this manner depends upon the sensitiveness of the levels used, and not all levels are sensitive enough to do good work with.

595. Q.—In making surface plates, is it necessary to work at more than one at a time?

A.—Unless the plate is worked up from a master plate, it is necessary to work at three plates, trying them together alternately.

596. Q.—Can a chuck drill be ground to cut larger than itself when enlarging a hole, provided the rest is set true and the lathe is in good condition.

A.—Yes. As much pains should be taken in grinding a chuck drill when it is desirable that it shall cut its exact size as in grinding any other drill.

597. Q.—How fast should a grindstone for grinding tools be run?

A.—Grindstones for grinding tools are run at speeds varying from 200 to 350 feet peripheral speed per minute. About 250 feet is a fair average. A good way to come at the speed is to mount the stone and turn it by hand until a speed is obtained at which the water will fly off, so as to begin to be troublesome. The speed at which it is to run should be a little less than this.

598. Q.—Will the hole bored with an ordinary boring bar, with one cutting tool, be oval, provided the tail block be set over out of line?

A.—It will be.

Screws and Screw Cutting.

599. Q.—How far should one thread measure from the next one when it is ⅞ inch pitch? What would be the pitch when there was one thread in ⅞ inch? Can you give me a rule for finding the pitch when the distance from one thread to the next is known?

A.—You seem to be confused by the pitch of a screw and the number of threads to the inch. These terms are frequently used synonymously, but for the sake of clearness they should not be so used. The pitch of a screw (single threaded) is the distance from any part of one thread to the similar part of the next one, hence the answer to your two first questions is ⅞ inch. Knowing this distance, you can find the number of threads to the inch by dividing the denominator of the fraction expressing the distance by the numerator. Thus, in your example, the pitch is ⅞ inch and the number of threads to the inch is $8 \div 7 = 1\frac{1}{7}$. Conversely, if you know the number of threads to the inch you can find the pitch by dividing one inch by the number of threads to the inch, thus 1 thread of $1\frac{1}{7}$ threads to the inch is $1 \div 1\frac{1}{7} = \frac{7}{8}$ pitch.

600. Q.—Please give a rule for selecting gears to cut threads on lathes, for both single and compound gearing.

A.—If the lathe is simple-geared and the stud runs at the same speed as the spindle, then select some gear for the screw, and multiply its number of teeth by the number of threads per inch in the lead screw, and divide this result by the number of threads per inch which you wish to cut. This will give you the number of teeth in the gear for the stud. If this result is a fractional number, or a number which is not among the gears which you possess, then try some other gear for the screw. But if you prefer to select the gear for the stud first, then multiply its number of teeth by the number of threads per inch which you wish to cut, and divide by the number of threads per inch on the lead screw. This will give you the num-

ber of teeth for the gear on the screw. If the lathe is compound, select at random all the driving gears, multiply the numbers of their teeth together, and this product by the number of threads you wish to cut. Then select at random all the driven gears except one, multiply the numbers of their teeth together and this product by the number of threads per inch in the lead screw. Now divide the first result by the second and you will have the number of teeth in the remaining driven gear. But if you prefer, you can select at random all the driven gears. Multiply the numbers of their teeth together, and this product by the number of threads per inch in the lead screw. Then select at random all the driving gears except one. Multiply the numbers of their teeth together, and this result by the number of threads per inch of the screw you wish to cut. Divide the first result by the last, and you will have the number of teeth in the remaining driver. When the gears on the compounding stud are fast together, and cannot be changed, then the driven one has usually twice as many teeth as the other, or driver, in which case you can, in the calculations, consider the lead screw to have twice as many threads per inch as it actually has, and then ignore the compounding entirely. Some lathes are so constructed that the stud on which the first driver is placed revolves only half as fast as the spindle. You can ignore this in the calculations by doubling the number of threads of the lead screw. If both the last conditions are present, you can ignore them in the calculations by multiplying the number of threads per inch in the lead screw by 4. If the thread to be cut is a fractional one, or if the pitch of the lead screw is fractional, or if both are fractional, then reduce the fractions to a common denominator, and use the numerators of these fractions as if they equaled the pitch of the screw to be cut, and of the lead screw, respectively. Then use that part of the rule given above which applies to the lathe in question. For instance, suppose it is desired to cut a thread of 25-32 inch pitch, and the lead screw has 4 threads per inch. Then the pitch of the lead screw will be ¼ inch, which is equal to 8-32 inch. We now have two fractions 25-32 and 8-32, and the two screws will be in the ratio of 25 to 8, and the gears can be figured by the above rule, assuming the number of threads to be cut to be 8 per inch

and that on the lead screw to be 25 per inch. But this latter number may be further modified by conditions named above, such as a reduced speed of the stud, or fixed compound gears. In the instance given, if the lead screw had been 2½ threads per inch, then its pitch being 4-10 inch, we have the fractions 4-10 and 25-32, which, reduced to a common denominator, are 64-160 and 125-160, and the gears will be the same as if the lead screw had 125 threads per inch and the screw to be cut 64 threads per inch.

601. Q.—I have three screws to cut, viz.: One 1¾ inches diameter, with 10.95 threads to the inch; one 1⅝ inches diameter, with 9.95 threads to the inch; one 1½ inches diameter, with 8.95 threads to the inch. What gears will cut these threads, leading screw being three threads?

A.—The gears can be found by simple proportion. Assuming a gear of 30 teeth for the stud gear, we state the case like this:

$$3 : 10.95 :: 30 : 109.5.$$

Hear a gear of 109.5 teeth is required, which is impossible, but if we double it and double the stud gear also, we will have 60 and 219 as the gears required. It will be noticed that both of these numbers are divisible by 3, so that 20 and 73 will cut 10.95 threads. We get at the other two threads in the same way:

$$3 : 9.95 :: 60 : 199$$
$$3 : 8.95 :: 60 : 179$$

The gears 60 and 199, therefore, will cut 9.95 threads, and 60 and 179 will cut 8.95 threads, and as these gears have no common divisor they cannot be reduced.

602. Q.—What decimal do you multiply the diameter of a threaded bolt by to ascertain the diameter at the bottom of the thread?

A.—The finding of the diameter at the bottom of the thread, though a very simple matter, is not quite so simple as you seem to think it. If the thread is U. S. standard, divide 1.3 by the number of threads per inch, and subtract this quotient from the outside diameter. The formula for this is

$$d = D - \frac{1.3}{n}$$

If the thread is a sharp V (which it ought not to be), divide

1.733 by the number of threads per inch and subtract the quotient from the outside diameter, the formula for this being:

$$d = D - \frac{1.733}{n}$$

603. Q.—Professor Sweet mentions a plan of lead screw for screw cutting "Using a short screw 8 or 10 inches long with a nut of the same length, the screw to be adjustable at any point along a splined rod." With this arrangement it would only cut screws equal to or shorter in length than the sleeve on which the lead screw is cut; was that the idea, or were there to be other parts so as to cut full the length of the lathe?

A.—Professor Sweet's idea in this is to provide a means of cutting nine-tenths to ninety-nine-hundredths of all the screws a lathe is ever required to cut, and to do it more accurately than is possible by the usual lead screw and nut; lathes with ordinary long lead screws being used for cutting screws longer than can be cut by this device. Professor Sweet informed us that he had never done anything in his shop that gave him better results than the adoption of this device on some lathes in which his crossheads and piston rods are threaded, whereby the pitch of the screws cut is kept accurate, and the great trouble formerly experienced from the fact that they could not be kept accurate, is avoided.

604. Q.—How can I figure the amount of stock necessary to cut a full thread? Please give figures for ¼-inch pitch.

A.—For a V thread, 1.733 divided by the number of threads per inch will give double the depth of the thread, or the amount of stock necessary for a full thread. For a U. S. standard thread, divide 1.3 by the number of threads per inch. Thus for a V thread of ¼-inch pitch, the amount of stock will be $\frac{1.733}{4} =$ .433 inch, and for a U. S. standard thread $\frac{1.3}{4} = .325$ inch.

605. Q.—Is it practical to cut a thread upon each end of a cylindrical casting without first turning the scale off the part to be threaded? The part for the thread is about 3½ inches in diameter and 1 inch long, all the rest of the casting being smaller than the bottom of the thread. The thread is 10 to the inch, sharp V, and to be cut with a collapsing die.

A.—We consider it decidedly unpractical, or impractical, to cut the thread as proposed. The scale will injure the die, the casting will not be round, and it will not be of the exact size required. It is, in our experience, quite difficult to cut a sharp V thread upon cast iron. The diameter of the piece to be cut should be a trifle smaller in all cases than that required for a full thread, and, therefore, the exact size is a matter of considerable importance.

606. Q.—What is the correct way to set a thread tool for a taper tap?

A.—Set it the same as for any other job of screw cutting, except that it should be set at right angles to the center line of the tap to be cut, instead of at right angles to the surface of the work.

607. Q.—What is the difference between cutting a common tap and a clearance tap for the clearance of dies?

A.—Hobs for hobbing dies with clearance are usually tapered the reverse way from taper taps in order to make the dies slightly larger at the rear.

608. Q.—I want to make out a table of angles of screw threads. What is the rule for measuring them when the pitch and circumference are known?

A.—Draw two straight lines perpendicular to each other. From their point of intersection measure off the pitch on one, and the circumference on the other. Join their extremities by a straight line, and thus complete a right-angle triangle. Then measure the angle formed by the hypothenuse and the line which represents the pitch; this will be the angle which the thread makes with the axis of the screw.

609. Q.—What is a "bastard" thread?

A.—The term "bastard" thread? does not mean anything more definite than that the thread is not one of the regular threads, such as U. S. standard, V, square or ratchet.

610. Q.—In cutting a long screw in the lathe with a heavy cut so that the screw is twisted more or less while the cutting is going, what will be the effect of the torsion upon the pitch? I, of course, do not mean that the screw is permanently twisted, but that it springs around away from the tool when it is cutting.

A.—We assume that the torsional movement will be greatest at the end farthest from the dog or driver, and that there will

be little or no twisting near the dog. In that case the effect will be to make the pitch of the screw somewhat less or finer than it would be if there was no twisting. In commencing the cut near the dog and cutting toward the tailstock end, as when cutting a left-hand screw or when cutting a right-hand screw with the tool at the back of the work, the effect of the torsional springing of the screw would then be to increase the pitch or to make it a little coarser. It might be possible to take advantage of this principle in cutting a new screw when the lead screw is known to be a little in error, if the error is known to be constant for the length of it. A prony brake might be applied to the tailstock end of the screw and a certain amount of torsion maintained during the cutting; and when the torsional strain was removed, the variation of lead, as indicated above, would be realized.

611. Q.—I run a lathe occasionally in which the gear wheel fixed on the mandrel has 42 teeth, while that on the stud into which it gears has 56 teeth. The lead screw has 9 threads to the inch. Will you please tell me how I can find the gears to cut any thread on this lathe? None of the rules seem to apply. What bothers me is the reduction of speed between the lathe spindle and the stud.

A.—The gears with 42 and 56 teeth are in the same proportion to each other as 9 (the number of threads on the screw) is to 12. In making calculations for the gears, therefore, you can ignore the difference of speed between the spindle and stud by assuming that the screw has 12 threads to the inch instead of 9, and then applying the usual rules. A very good plan when complications of this or any other kind arise is to place on the stud and screw gears of equal size, and then ascertain what number of threads to the inch the lathe will cut with those gears. This, then, will be what may be called the effective pitch of the screw and should be used in making computations for the gears, regardless of what the screw itself measures.

612. Q.—Will you please give the method of obtaining the width of flat and depth of thread in the Sellers system; also the process if the threads were divided into 10 parts instead of 8?

A.—The width of the flat in the Sellers or U. S. system is always one-eighth the pitch of the thread. There are many

tables published giving the size of the bolts at the bottom of the thread, from which it is of course easy to derive the depth of the thread. In the absence of these it can be found by dividing .65 by the number of threads per inch. If the threads were flatted to one-tenth their depth, instead of one-eighth, the flat portions would be one-tenth of the pitch in width. A sharp V thread is, in section, an equilateral triangle, each side of which equals the pitch of the thread. The perpendicular hight of such a triangle is equal to the side multiplied by .86603. Hence, you can find the depth of thread when flatted one-tenth of the depth by multiplying the pitch by .866 and taking four-fifths or two-tenths of the product, one-tenth being for the top and one-tenth for the bottom of the thread.

613. Q.—How can I set a thread tool when the tailstock is set over to cut a taper thread?

A.—Set the tool by the straight or parallel part of the tap, and not by the taper part. The angle with the straight surface should be equal on each side of the tool.

614. Q.—Please state the correct method of catching threads in a lathe with a scale or rule.

A.—Any method will answer by which the carriage can be run back an even number of inches while the lathe is standing still. One way of doing this is to simply lay the scale on the lathe bed so that the carriage will pass over it, stop the lathe when the edge of the carriage is in a certain place, run back any number of inches, and close the nut again; or two chalk marks can be made on the bed of the lathe, and the position of the carriage gaged by them.

615. Q.—Can you give me a rule for chasing a screw of any number of threads to the inch without using a backing belt?

A.—This may be done on any lathe in which the nut of the leading screw is in halves, and made to unlock from that screw by suitable mechanism. With such a lathe any pitch which is a multiple of the pitch of the lead screw, or any pitch of which the pitch of the lead screw is a multiple, may be cut by simply tripping the nut, moving the slide back by hand, and connecting the nut and screw again, it being impossible to so connect them with the tool in any position but the right

one. For any other pitch proceed as follows: Bring the slide, with the tool properly set, back to a position for starting the cut, and note that position lengthwise of the lathe with reference to some fixed point, as the tailstock, or a mark on the lathe slide; also make a mark on the face plate, and and note its position with reference to its revolution. Then, after the tool has traversed the length of the screw to be cut, unlock the nut, bring the slide back to position noted, lock the nut when the mark on the face plate is in position noted, and proceed with another cut. It will at first be necessary to stop the lathe to note positions and connect the nut and screw, but a little practice will enable you to cut almost any screw without stopping. We have known operators who removed their backing belts from choice, cutting screws of all descriptions with a single belt.

616. Q.—What is the best lubricant to put on a bolt that is 4 inches diameter and has three threads to the inch? The bolts are used in the main bearing of a gang, and we have lots of trouble in getting them loose.

A.—We would use tallow liberally, both on the threads and on the bearing faces of the nuts.

617. Q.—What is the ratio of the tensile breaking load of a threaded rod and a rod of the same material, having a diameter equal to the diameter of the threaded rod at the base of the threads?

A.—The tensile strength varies with the cross-sectional areas of the rods. In computing the strength of the threaded rod we take the area in square inches of the circle at the base of the thread, and multiply it by the tensile strength per square inch, the result will be the load. For computing the strength of a solid rod we employ the same rule, taking, of course, the cross-sectional area of the rod. According to your question, the area of the solid rod and the area of the threaded rod at the base of the thread are equal, hence both rods will require the same breaking load, consequently the ratio is 1.

618. Q.—What is the double depth of a sharp V thread of the following pitches: 28, 30, 32, 36, 40, 13 and 64?

A.—The vertical hight of an equilateral triangle is .866 of one of its sides, and the depth of a sharp V thread is therefore .866 of the pitch, or of distance from the center of one thread to the

center of the next. Multiplying .866 by 2 we have 1.7328, and this divided by the number of threads per inch gives the double depth of the thread. In this case if we take 1.733 the results will be near enough, and dividing this by the various numbers we have for the double depth of the various threads given: 28 = .062 inch; 30 = .0577 inch; 32 = .054 inch; 36 = .048 inch; 40 = .0433 inch; 13 = .1333 inch; 64 = .027 inch.

619. Q.—What is the most accurate way to cut double or triple screw threads in the lathe, so that the threads will be of the same thickness?

A.—There are several ways to do this correctly, each of them therefore as "accurate" as any other. If a double male thread is being cut on the centers, the work being driven by a dog with a tail in a slotted face-plate, when one thread is cut the center may be slackened and the work shifted halfway around, bringing the tail of the dog in the opposite slot of the face-plate. It must be ascertained that the slots are laid out correctly. If the work is driven by a stud in the face-plate against a tail-less dog, two studs in the face-plate may be placed opposite each other and the work shifted so as to drive by one stud and then by the other. So, too, for triple threads three equally spaced slots in a face-plate or three studs may be used. In all the operations here referred to it is understood that the lathe is not in motion when the changes are made. In cutting either male or female threads they may be in many cases cut double or triple by unlocking the nut on the feed-screw, moving the rest along and closing it upon another thread. Thus if the pitch of a double thread to be cut is an odd number to the inch, while the pitch of the lead screw is an even number to the inch, it is only necessary when one thread is cut, or partially cut, to open the nut, move the rest along half an inch and then close it again to bring the tool in position for cutting the other thread. Thus, if a double thread with a pitch of 5 to the inch is to be cut. while the lead screw is 4 to the inch, it is only necessary to keep moving the rest along two threads at a time on the lead screw, and the change of cut is made from one thread to the other on the work. This applies also to any other common unit of measure for the two threads. If the pitch of a thread to be cut is 6 to the inch, while the pitch of the lead screw

is 4 to the inch, then for each half inch one will be odd and the other even, and a 6-pitch double thread may be cut by successively moving the rest along a single thread on the lead screw. If the pitch of the lead screw is 3 or 6 to the inch, triple threads may be cut to any pitch, except 3 to the inch or multiples of 3, by successively opening the nut and moving the carriage along a third of an inch and then closing the nut again. Other opportunities in this line will occur to the latheman who is at all expert at arithmetic. But the common practice in cutting double or triple threads, and which covers all cases, is to throw the train of screw-cutting gears out of mesh, move the lathe spindle around a half or a third of a turn, as the case may require, and then put the gears in mesh again. To do this accurately it is usually necessary to count the teeth of the driving gear, and for double threads this gear must therefore have an even number of teeth, for triple threads a number divisible by 3, and so on. Having, say, thirty teeth in the driving gear, the lathe being stopped, a tooth of the driving gear and the space into which it meshes in the intermediate gear are marked with chalk, also the opposite tooth on the driving gear. The intermediate gear is dropped out of mesh with the driver, remaining still in mesh with the screw; the lathe spindle is turned halfway around, bringing the other marked tooth in the required position to mesh into the marked space in the intermediate gear, which is then brought into mesh and secured, when all is ready for cutting the other thread. The driving gear in this case was moved along fifteen teeth. In cutting a triple thread it would have been moved along only ten teeth at a time. If the driving gear is on a stud which runs at one-half the speed of the lathe spindle, then for cutting double threads, the driver must make a complete revolution out of mesh and the same tooth be then brought to mesh in the same space. For triple threads it would make two-thirds of a revolution at a time, and so on. In making the changes it will make no difference in which direction the spindle is turned. The pitch of double or triple threads is the distance the nut will traverse the screw for a complete revolution multiplied by the number of times this distance is repeated in an inch of travel.

620. Q.—In cutting milling cutters, how is the diameter divided to bring the cutting teeth out right at the last tooth?

A.—The diameter has nothing to do with it. The indexing head rotates the cutter the exact proportion of the complete rotation that is required according to the number of teeth to be cut. The last tooth will be of the same width as the rest, and after the last tooth is cut the next movement brings the cutter into the position for cutting the first tooth again.

621. Q.—What is the difference between the United States standard pipe thread and the English pipe thread, and the Whitworth screw thread for gas, steam and water piping, as to shape and angle of thread; also, is the taper alike in all above cases?

A.—The pitch of the thread of wrought-iron pipes in the United States is as follows: ⅛ inch, 27; ¼ and ⅜ inch, 18; ½ and ¾ inch, 14; 1 to 2 inches, 11½; all above 2 inches, 8. The pitch of the Whitworth pipe threads is: ⅛ inch, 28; ¼ and ⅜ inch, 19; ½ and ¾ inch, 14; 1 to 2 inches, 11; all above 2 inches, 8. The angle of the Whitworth thread is 55 degrees, with one-sixth of the top and of the bottom rounded. The angle of the United States standard thread is 60 degrees, with a flat at the top and the bottom of the thread equal to one-eighth of the pitch. The taper of United States pipe taps is ¾ inch to the foot; the taper of the male thread, as cut by the dies, is usually less than this. English pipe threads are not tapered.

622. Q.—Is there a United States standard for the diameters of the heads of cap screws? Most of the screw manufacturers add ¼ inch to the diameter of the screw to obtain the diameter of the head across the flats for sizes above ½ inch.

A.—The United States, or Sellers, standard applies properly only to bolts and nuts; but there is no reason why it should not be equally applicable to cap screws. The standard of the leading screw makers seems to have been adopted with a view to saving as much stock and labor as possible. It gives an ugly head with insufficient bearing, and it is strange that it is so widely accepted.

623. Q.—What should be the angle of a screw countersink, or is there any standard?

A.—There has been until recently perhaps no recognized

standard, but the Morse Twist Drill and Machine Company make their countersinks with an included angle of 82 degrees, and this angle, which has been adopted as the result of considerable inquiry into the matter, may be regarded as the standard.

624. Q.—What is the correct pitch of a 2⅜-inch United States standard screw; also say whether the next size above should be taken when not given in the table?

A.—There is no United States standard 2⅜-inch screw. A screw which is made to the United States standard conforms to it not only in the shape of the thread and number of threads to the inch, but also in diameter, and there is no provision for a 2⅜-inch screw, which is the reason it is not given in the tables. If you make such a screw it will not be United States standard, no matter what pitch you make it, and you can therefore choose your own pitch.

625. Q.—Some time since I had occasion to make a double-threaded nut and screw. I divided the thread on the screw without trouble, but had trouble in dividing the nut. How can it be done?

A.—The plan usually employed is to divide and mark two of the screw gears, stop the lathe, slip them out of gear, and turn the spindle one-half and one-third, as it may be a double or triple thread, putting them in gear again by the marks.

626. Q.—Is it correct to say a thread is chased when it is cut by the use of a V tool and gearing in an engine lathe?

A.—There is no rule or law except custom in this respect, and it has become customary in many localities to call the operation of cutting screws in an engine lathe, chasing.

627. Q.—What grade of oil is used by the large screw manufacturers for cutting screws on screw machines, and general screw-machine work?

A.—The best lard oil has been found the most satisfactory on general screw work where it is desirable to maintain accurate standard sizes. On very fine screw work it is necessary to use the best sperm and even finer grades of oil.

628. Q.—Will you give me the diameter of a roll that, in going 31 threads on a screw that is 20 threads to the inch, will make one turn; or, in other words, make one turn in going round the screw 31 times, the screw being $\frac{55}{1000}$ inch diameter at the bot-

tom? As I do not care about the top of threads, I do not give the size.

A.—You have not stated all the conditions necessary to know in giving an answer; but assuming that the axis of the screw and the axis of the roll are parallel one with the other, then the diameter of roll will be .068 × 31 = 1.798 inches. But if the roll is a disk which goes between two threads, and is inclined to suit the angle of the spiral, then its circumference must equal the length of the helix for 31 threads. The length of this helix is 5.8574 inches, and the diameter of the roll will be this divided by 3.1416, which gives 1.8645 inches.

629. Q.—What is the rule for the width and depth of a square thread?

A.—The width is one-half the pitch, and the depth 19-20 of width.

630. Q.—Will an ordinary square-nosed (or cutting-off tool) set at a right angle to the centers cut a good square thread? If not, what should be the shape of the tool?

A.—Such a tool will cut a good square thread provided it is short enough to give it sufficient rigidity to prevent springing, and provided also that the angle of the spiral of the thread is not so great as to make the tool bind on one side. The shape of the tool should be made similar to that of an ordinary cut-off tool, except that it should be shorter. The blade should be thinner at the back than at the cutting point. Then it should incline to the right or left at about the same angle as the spiral of the bottom of the thread.

631. Q.—Will you please tell me how to calculate the angle of the sides of a square thread tool to cut a tap of rapid pitch?

A.—Find the diameter of the tap at the middle of the hight of the threads, and multiply this by 3.1416 to get the circumference at this point. Divide the pitch of the spiral, *i. e.*, the distance from the center of one thread to the center of the next thread in a single-threaded tap, by this circumference and the result will be the tangent of the angle. Then find the corresponding angle in a table of natural tangents. This angle when so found represents the angle of the center line of the cutting portion of the tool measured from the vertical, and the sides of the tool should be given the required clearance besides this, so that the angle on the advance side of the tool will be

slightly greater, and that the rear slightly less than the angle previously determined.

632. Q.—What is the proper taper per inch for pipe threads?

A.—The taper is 1-32 inch per inch in length, or 1 in 32 to axis of tube, which means ¾ inch taper per foot.

633. Q.—In chasing a 14-inch pipe flange, is it proper to set the point of the tool to a gage placed against the bored part, or should the gage be set perpendicular to the face of the flange?

A.—The point of the tool should be set to a gage placed perpendicular to the face of the flange.

634. Q.—How many threads per inch are there on a 2-inch pipe tap? I have always thought that it was 11½ threads, now I am inclined to think it is 11 2-3, from the fact that I made a special tap with the regular taper, and geared the lathe to cut 11½ threads, but it did not pass, as the threads did not fit in those of a bought pipe tap. I tried my taps with two other pipe taps, and I found these to be the same as the first one. Now, where is the trouble, or where is my mistake?

A.—The correct number of threads per inch for a 2-inch pipe tap is 11½, measured on a line parallel with the center line, and if the threads are cut on a lathe with a taper attachment, you will obtain correct results; if, on the other hand, the threads are cut with the footstock set out of line, as was probably done in your case, we should expect results such as you complain of. It is also possible that the bought taps were not correct, as these may have slightly expanded during hardening.

635. Q.—Please explain the symbols given to indicate the size of screws such as 4—32, 6—32, 4—40, etc.

A.—The first number in each set indicates the gage number for the diameter of the screw, and the second number indicates the number of threads per inch.

636. Q.—Have the French a certain number of threads per centimeter, as we have a certain number of threads per inch?

A.—Metric threads, so far as they are used in France, are usually based on the actual distance from center to center of contiguous threads, stated in millimeters; that is to say, an 8-millimeter thread is one which is 8 millimeters from center to center of threads. A 2-millimeter thread would be one having a distance of 2 millimeters from center to center of con-

tiguous threads, and of course such a thread would have five threads per centimeter, although it would not be referred to as five threads per centimeter, but as a 2-millimeter thread.

637. Q.—In the French or metric system of screw threads the size of the thread is designated by the pitch of the single thread, instead of using some number, usually a whole number, of threads to the inch as we do. Is not the French system less convenient than our own when it comes to figuring screw gears for an engine lathe, and how do they do it, anyway?

A.—The metric system of thread designation is fully as convenient as our own in this respect. With us we usually have two or three stud gears, with large differences in the numbers of their teeth, and most of the changes for the different threads are made in the screw gears. Thus with a lead screw five to the inch, and with the stud turning at the same speed as the spindle, a set of gears running as follows might be used:

Number of Threads.	Stud.	Screw.
2	80	32
3	80	48
4	80	64
5	80	80
6	80	96
7	40	56
8	40	64
9	40	72
10	40	80
11	40	88
11½	20	46
12	20	48
13	20	52
14	20	56
16	20	64
18	20	72
20	20	80
24	20	96

Number of gears to the set, 12.

For cutting metric threads a screw with a pitch of 5 millimeters would be quite convenient for a small engine lathe, and that pitch would also be quite nearly the same as our five to the inch.

A convenient set of change gears for the common metric threads would then be as follows:

Pitch of Thread, Millimeters.	Stud.	Screw.
1	20	100
1.5	30	100
2	40	100
2.5	50	100
3	60	100
3.5	70	100
4	80	100
4.5	90	100
5	50	50
5.5	55	50
6	60	50
6.5	65	50
7	70	50
7.5	75	50
8	80	50

Number of gears to the set, 13.

The finest thread is here at the top of the list, while in the American system it is at the bottom. One millimeter pitch is about 25 to the inch and is used for 6 millimeters diameter, which is a little less than a quarter of an inch. Eight millimeters pitch is a little over 3 to the inch, and is used for 96 millimeters diameter, or about 3¾ inches. The stud gears in the above list are obtained for the upper half of it by multiplying the pitch by 20, and for the lower half by multiplying by 10.

638. Q.—How can we arrange our lathe to cut metric threads?

A.—Metric threads are usually counted as so many threads per centimeter, and as 1 inch is to 1 centimeter as 1 to .393704, it is only necessary to reduce the motion of the screw in that proportion to give as many threads per centimeter as the lathe would ordinarily cut per inch. This can be done by introducing into the screw-cutting train a compounding stud having two gears—one with 50 teeth, the other with 127. These two gears are in the proportion of 1 to .3937007, and the error between this and exactitude is so small as to be negligible.

Gears and Gearing.

639. Q.—What is meant by saying a gear has 6 pitch or 8 pitch?

A.—A gear, 6 pitch, means that it has 6 teeth for every inch of the diameter of the pitch circle; a gear, 8 pitch, has 8 teeth for every inch of the diameter of the pitch circle. Thus a gear, 8 pitch, and 5 inches in diameter at the pitch circle, has $8 \times 5 = 40$ teeth; or a gear, 6 pitch and 48 teeth will be $48 \div 6 = 8$ inches diameter at the pitch circle. The terms, 6 pitch, 8 pitch, etc., are called the diametral pitch.

640. Q.—How is it determined that the pitch of a gear is 7 or some other number?

A.—We assume that you refer to the diametral pitch. If the circumference of the pitch circle is divided by the number of teeth in the gear, the quotient will be the circular pitch. In the same manner, if the diameter of the pitch circle is divided by the number of teeth, the quotient will be the diametral pitch. Thus, if a gear is 12 inches pitch diameter, and has 84 teeth, and if we now divide 12 by 84, we have $\frac{12}{84} = \frac{1}{7}$ inch for the diametral pitch of this gear. Generally, in speaking of diametral pitch, the denomination of the fraction only is named. One-seventh inch diametral pitch is then called 7 diametral pitch. That is, it has been found more convenient to take the reciprocal of a diametral pitch in making calculations. The reciprocal of a given number is the quotient obtained by dividing 1 by the given number. Thus the reciprocal of 1-7 is 7, because 1-7 goes into 1 seven times. From the foregoing we have the following definition: Diametral pitch is the number of teeth to one inch of diameter of pitch circle. Thus 1-7 inch diametral pitch we would call 7 diametral pitch, because there are 7 teeth to every inch in the diameter of the pitch circle.

641. Q.—How can I find the number of teeth that will go in a gear?

A.—Divide the circumference of the pitch circle by the circular pitch, the result will be the number of teeth.

642. Q.—How may I find the pitch of a gear?

A.—If you wish to find the pitch of a gear which has been

made, use the following rule: Divide the outside diameter of the gear—that is, the diameter of the addendum circle, by the number of teeth plus 2, the result will be the diameter pitch; divide this by .3183, the result will be the circular pitch.

643. Q.—Why does dividing 2.157 by the diametral pitch give the depth of a gear tooth, and where is this 2.157 derived from?

A.—Diametral pitch means number of teeth per inch of diameter, and the actual pitch of a diametral pitch gear—that is, the distance from the center of one tooth to the center of the next on the pitch line, is therefore 3.1416 divided by the pitch, because the circumference of a pitch line is 3.1416 times the diameter of the pitch circle. Since the thickness of a gear tooth at the pitch line is equal to the space and therefore equal to half the pitch, the thickness of a tooth of given pitch is found by dividing 1.57 by the pitch, because 1.57 is half of 3.1416, and the clearance at the bottom of the tooth is 1-10th of the thickness and is therefore obtained by dividing 1.57 by the pitch, .157 being 1-10th of 1.57. The working depth of the tooth is twice its diametral pitch and is obtained by dividing 2 by the pitch. Consequently when the whole depth is to be obtained, *i. e.*, the working depth plus the clearance, we add 2 and .157 and divide divide their sum by the pitch. Thus

$$\frac{2.157}{P} =$$

whole depth of tooth. Applying this to an 8-inch pitch gear we have

$$\frac{2.157}{8} = .2696,$$

or $2.157 \div 8 = .2696$ inch for the total depth of tooth.

644. Q.—I have a worm gear to cut, and would like to know how far off the center, per foot, to set the index to get the angle for the cutter, the worm being 2 inches diameter, 4 pitch.

A.—We assume that 2 inches is the pitch diameter, and that by 4 pitch is meant 4 to the inch. Two inches being the diameter, the circumference will be $2 \times 3.1416 = 6.2832$ inches, and ¼ inch will be the tangent of the angle of which 6.2832 inches is in this case the radius. The tangent of the same angle for a radius of 12 inches would then be 6.2832 : 12 :: .25 : .4774 inch, and this would be the distance per foot to set over. Then $.4774 \div 12 = .0398$, which is the tangent for radius 1, and the

corresponding angle, from a table of tangents, is 2° 17′; or, according to the usual machine-shop accuracy, a little less than 2 1-3 degrees.

645. Q.—Is there a formula for getting the cutting depth of worm thread, where the pitch is given, without using a worm-thread gage?

A.—The rule is to make the depth of the thread equal .636 of the pitch. For instance, if the worm has 5 threads per inch, then its pitch will be .2 of an inch, and this multiplied by .636 equals .1272, which is the depth of the thread according to this formula.

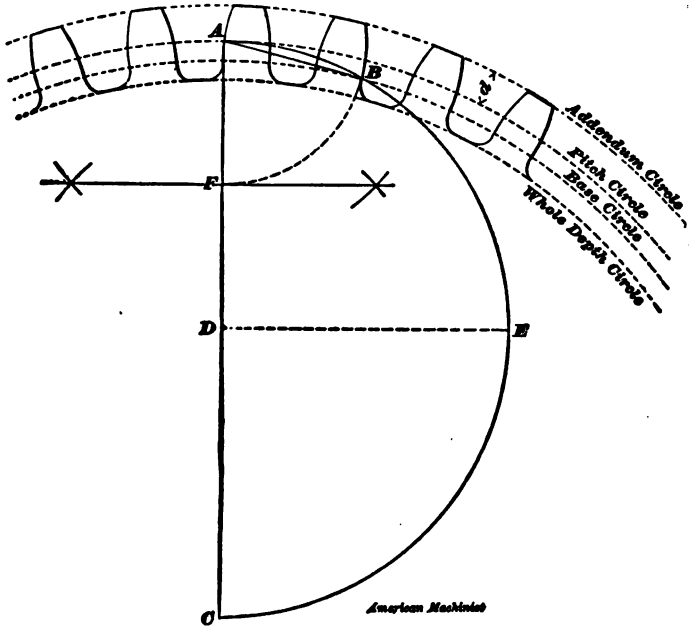
646. Q.—How would you ascertain the depth of a worm, the pitch being given, saying, "I want to cut a worm ⅞ inch pitch"?

A.—The depth is found in the same manner as the depth of a rack tooth, and is equal to the depth of a rack tooth of the same pitch. Computing it by the diametral system the depth would be practically .6 inch; by circular pitch .6125 or .61; the rule for the latter being to make the tool depth equal .7 of the pitch.

647. Q.—Please give me a method for finding the base circle for the centers of arcs for the involute or single-curve system gears.

A.—Let *A C* be the radius of the pitch circle of the gear. Bisect *A C* at *D*, and from *D* as a center, and with the radius *A D* or *D C* draw the semi-circle *A E C*. Bisect *A D* at *F*, and from *A* as a center, and with the radius *A F* draw an arc, cutting semi-circumference *A E C* in the point *B*. From the center *C*, and with a radius equal to *C B*, draw a circle. This circle will be the base circle on which all the centers of the tooth arcs are located; and the radius of each tooth arc is equal to *A B*, which, as will be seen by the construction, is equal to one-fourth of the radius *A C* of the pitch circle. To find the addendum circle, multiply the circular pitch by .3183, the result will be the distance *d* from the pitch circle to the addendum circle. The distance from the pitch circle to the whole depth circle is equal to *d* plus 1-10th of the thickness of the tooth at the pitch line. Some mechanics prefer to use 1-16 in place of 1-10 of the thickness of the tooth. Set off on the pitch circle equal parts, each equal to one-half the circular pitch, and through these points of division draw the tooth arcs with a ra-

dius *A B* and centers on the base circle, terminating in the addendum circle, and join these arcs to the whole depth circle



by small arcs or fillets. The radii of these small arcs should be equal to 1-6 of the widest part of the tooth space.

648. Q.—Should the pitch diameter be a whole number or a whole number and a fraction?

A.—The pitch diameter may be a whole number, or a whole number and a fraction, but in any case it should be such as can be conveniently measured. According to the above construction the diameter of the base circle is .968 of the diameter of the pitch circle. The above relates to wheels having 30 teeth or more.

649. Q.—Can involute teeth be used for internal gears?

A.—Yes, provided there are at least twelve more teeth in the internal gear than in the pinion, otherwise the internal teeth are liable to interfere with those on the pinion, and will

need to be "doctored" or rounded over until they will pass. It is also advisable that the pinion should not have less than thirty teeth, otherwise the teeth are liable to be weakened at the root.

650. Q.—Should gears work with the teeth lubricated or should they run dry?

A.—Gears which transmit power should have the teeth lubricated; gears which transmit very little power, or practically transmit no power, should run without lubricating the teeth. For instance, the back gears of a lathe should be lubricated, but the teeth of the change gears should run with the teeth dry.

651. Q.—How is the pitch of gear wheels figured, say 5 or 8 pitch? How do you get the pitch?

A.—Assuming you have gear wheels that you wish to find the pitch of, it is done by the following rule: Take the number of teeth in the gear and add 2; divide this by the outside diameter in inches, and the result is the diametral pitch. This rule expressed in a formula is:

$$P = \frac{N + 2}{D}$$

where P = diametral pitch, N = number of teeth, and D = outside of diameter of gear. Taking, as an example, a gear wheel having 40 teeth, and which we find measures 8 2-5 inches or 8.4 inches outside diameter; then, substituting for the letters in the formula their values for this case, we have

$$P = \frac{40 + 2}{8.4}$$

and 42 divided by 8.4 gives 5, which is the pitch. Take another gear with the same number of teeth (40), and which we find measures 5¼ inches outside diameter, for this case the formula becomes

$$P = \frac{40 + 2}{5.25}$$

and 42 divided by 5.25 gives 8, which is the required pitch. Send to the Brown & Sharpe Manufacturing Company, Providence, R. I., for their catalog, and on pages 204 and 205 you will find a number of very simple formulas for gears. A little study of these and the application of them to a few gears will make you familiar with the subject. It is very easy.

652. Q.—Why is a small gear called a "pinion"?

A.—We do not know. The etymology given in the dictionaries seems to have nothing to do with the case. It is suggested that the term comes from the fact that originally the teeth of pinions were made of rods or pins, and the large gear may have been called the "tooth wheel," and the small wheel the "pin one," or "pinion."

653. Q.—What is the rule for computing the diameter of the blank for a spiral wheel?

A.—There is but a slight difference in the rules for finding the diameters of blanks for spur and spiral gears. The diameter of the pitch circle of a spiral gear having the same number of teeth, and the same circular pitch as a spur wheel, is equal to the diameter of the pitch circle of the spur gear. Hence the diameter of the pitch circle for either gear is found by the following rule: Multiply the number of teeth in the gear by the diameter pitch, the product will be the diameter of the pitch circle. The diameter pitch is found by multiplying the circular pitch by .3183. Hence the above rule for finding the diameter of the pitch circle for spiral or spur gear can be stated as follows: Multiply the number of teeth in the gear by the circular pitch and by .3183, the result will be the diameter of the pitch circle. Expressing this rule in symbols, we have

$$N \times P \times .3183 = D, \qquad (1)$$

in which N = number of teeth in the gear, P = circular pitch, and D = diameter of the pitch circle. For spur gears, nearly all mechanics make the addendum of the teeth—that is, the distance from the pitch circle to the outer circle of the teeth, equal to the diameter pitch, consequently add twice this distance, or, in other words, twice the diameter pitch to the diameter of the pitch circle, the result will be the whole diameter of the gear, or the diameter of the blank. If, for instance, the diameter of the pitch circle is 4 inches, and the diameter pitch—that is, the circular pitch, multiplied by .3183 = 1-10 inch, then the diameter of the blank will have to be 4 2-10 inches. This rule for finding the diameter of a blank for spur gears can be stated in symbols as follows:

$$(N + 2) \times P \times .3183 = d, \qquad (2)$$

in which d = diameter of the blank; all the other letters denote

the same quantities as in formula (1). For spiral gears it is customary to make the addendum of the teeth equal to normal pitch (not circular pitch) multiplied by .3183. In spur gears the normal pitch and circular pitch are equal, but in spiral gears the normal pitch is the shortest distance between the centers of two consecutive teeth measured along the pitch surface and this is less than the circular pitch of spiral gears. Hence for finding the diameter of the blank for a spiral gear we have the following rule: Multiply the number of teeth by the circular pitch and by .3183, add to this product twice the normal pitch multiplied by .3183, the result will be the diameter of the blank. If, for instance, we find that the product of the number of teeth into the circular pitch multiplied by .3183 is equal to 4 inches (which is the diameter of the pitch circle of this gear), and the normal pitch multiplied by .3183 is equal to 1-12, then the diameter of the blank will be 4 2-12 inches, and not 4 2-10 inches, as was found for the diameter of the blank of the spur gear. The rule for finding the diameter of the blank for spiral gears may be expressed in symbols as follows:

$$N \times P \times .3183 + 2\ (p \times .3183) = d, \qquad (3)$$

in which p = normal pitch, all the other letters denoting the the same quantities as before.

654. Q.—Is there any difference in the running of these gears when the angle of the spiral is not the same in both wheels?

A.—When two spiral gears are in mesh the angle of spiral should be the same in both gears; in this case the angle of spiral should be 45 degrees.

655. Q.—How can I get the pitch diameter of a pinion or gear that has been lost from a pair?

A.—First find the diameter of the pitch circle of the gear on hand. This is found by subtracting from outside diameter of the gear, or the addendum circle, the whole depth of the tooth, and adding to the remainder one-tenth of the thickness of the tooth measured on the center of its depth, all in inches, the result will be the pitch diameter. Multiply this diameter by the number of teeth in the lost gear, and divide the product by the number of teeth of gear on hand, the quotient will be the pitch diameter of the lost gear.

656. Q.—What is the greatest possible pitch that can be used for two

spiral gears, respectively 4 and 2 inches diameter? The shafts are at right angles to each other, and the gears should run as easily as possible.

A.—The number of teeth in the small wheel should not be less than 12; from this the pitch is easily computed.

657. Q.—I have a series of gears working together. One has 133 teeth; one, 255 teeth; and one, 327 teeth. I start the first gear (133 teeth) at 20 revolutions per minute, say, at 6 o'clock in the morning. When will the wheels be in the same position as when they started?

A.—Find the least common multiple of 133, 255 and 327; this multiple is 3,696,735. Divide this number by 133, which gives us 27,795 for the number of revolutions which the wheel with 133 teeth will have to make to bring all the gears back into the original positions. This wheel makes 20 revolutions per minute, hence it will have to run $\frac{27,795}{20} = 1,389.75$ minutes, or 23 hours 9¾ minutes to bring the whole series of wheels into the original position. The reason for dividing the least common multiple by the number of teeth in the small wheel is that its speed is given.

658. Q.—What portion of cut gear teeth should show contact to run quietly? Some claim that the driver should show bearing from the pitch line to the point, while the driven should show from the pitch line to the root of the tooth. Others claim that all gearing should bear only from the pitch line to the points of the teeth; and yet there are others who hold that the bearing should be from the point to the root.

A.—Each tooth should show contact along the whole face, that is, the portion lying between the pitch line and the end of the tooth, and it should also show contact along a part of the flank of the tooth.

659. Q.—What is the meaning of the term "staggered teeth," as applied to gears?

A.—It means that the gear is composed practically of two gears placed side by side and bolted together so as to make in effect one, but with the teeth of one-half standing opposite the spaces of the other.

660. Q.—How are the pitch diameters of bevel gears measured?

A.—The pitch circle of a bevel gear is understood to be the pitch circle of the outer end of the teeth. The diameter is obviously the same as that of a spur gear whose pitch diameter is equal to that of the outer end of the bevel teeth.

Patternmaking and Woodworking.

661. Q.—I notice that on warm days carpenters usually take pains to lay their saws and chisels in the shade. Is the heat of the sun sufficient to draw the temper of such tools?

A.—There is an opinion among some that continued exposure to the sun's heat will lower the temper of cutting tools. Our opinion is that it will not.

662. Q.—What is the best wood for making patterns for brass castings; also is it necessary to make any allowance for shrinkage in the castings on hollow patterns from 1 to 3 inches in diameter?

A.—Mahogany is probably the best wood for small fine patterns. Metal is still better where it is necessary to produce castings of a uniform size. It is necessary to allow for shrinkage upon all patterns for brass castings, the amount of which depends upon the shape and size of the piece, and for fine work it can only be determined by experiment.

663. Q.—What is the best preparation to use to prevent the dampness of the sand from penetrating wood patterns? Is there anything better than shellac?

A.—From the practically universal use of shellac for wooden patterns, we judge that nothing better is known for the purpose. The use of lampblack with the shellac is generally condemned as being only a device for concealing bad pattern work, but we are inclined to think that it also helps to make the shellac more effective in protecting the pattern.

664. Q.—What is the best way to prepare shellac for patterns?

A.—The way with which we are familiar is to simply dissolve the dry shells in alcohol, and dilute with alcohol to any required consistency. The shells dissolve quite slowly, requiring usually a day or so. If kept in a warm place the process is hastened, but the alcohol evaporates more rapidly. It should be kept tightly covered.

665. Q.—Does it make any difference whether the shellac is mixed with grain alcohol or with methylated spirits?

A.—As the solvent simply evaporates and leaves the deposit of shellac, we do not see how it can make any difference.

666. Q.—Of what is the so-called white metal composed which is often used by patternmakers for patterns?

A.—There are a number of alloys called white metal, and the kind to be adopted will depend much on the form of pattern. The following may answer your purpose: 10 ounces lead, 6 ounces bismuth, and 4 drachms of antimony; or, 2 pounds of antimony, 8 ounces of brass, and 10 ounces of tin.

667. Q.—Where can I get some soft metal like babbitt suitable for pattern work, but which will not shrink when cast.

A.—We do not know where you can obtain a soft metal which will not shrink when cast. It is said that the following alloy will not contract when cooling—10 pounds of lead and 2 ounces of antimony. The antimony is added when the lead is in a state of fusion. The antimony gives hardness to the lead, but prevents its contraction from cooling.

668. Q.—I want to stain beechwood black without checking it and have the stain penetrate the wood deep enough to finish, say 1-64th part of an inch. The articles are small—handles, knobs, etc. I have tried sulphate of iron and logwood; vinegar, iron and logwood. The surface shows up all right, but the color does not penetrate, unless boiled, which checks the wood?

A.—A similar difficulty has been overcome by forming a partial vacuum in a close vessel containing wood to be stained and dye used. Some of the air being exhausted from the pores of the wood the dye was drawn into the wood when the vacuum was removed or air was let into the vessel.

669. Q.—What is patternmakers' varnish made of, and how applied so that it will not peel off?

A.—Patternmakers' varnish is made by dissolving shellac in alcohol until of the proper consistency. There is no danger of its peeling off if applied in light coats. After applying the first coat, sandpaper over with fine sandpaper.

670. Q.—I am making a sand belt for smoothing up the edges of blocks. I have a new belt, made mostly of canvas, but containing a very little rubber; would glue hold as well on this belt as on one made entirely of canvas?

A.—It would be better to use a belt made expressly for a

sand belt, entirely of canvas, yet glue will hold fairly well on the rubber center belt.

671. Q.—What kind of sand will be best?

A.—Any hard sand will answer which under the microscope proves to be sharp on the edges. Certain kinds of sand, river and beach sand especially, prove to have dull, round corners when examined. Such sand is useless for sand-belt purposes.

672. Q.—How fast should a sand belt run?

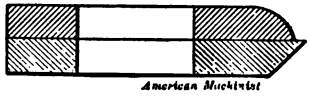
A.—About 4,000 lineal feet per minute will give good results.

673. Q.—Is common glue strong enough, or what kind of glue is best?

A.—Common glue will do, but it pays to buy the best glue in the market.

674. Q.—What will prevent wood moldings from being pitted as they are run through the machine? We have trouble of this kind; we have the same trouble whether we use the blower or not. Our molding machine runs at a speed of 3,700 revolutions per minute.

A.—There are two methods for preventing this trouble; one is to fit a scraper or doffer and fasten it in the machine between the cutters and the feed roll. The other is to fix a cap on the tool or cutter similar to the cap on a hand plane bit something



like that shown in the accompanying sketch, leaving as little projection beyond the cap as possible. This method is to prevent the chips clinging to the edge of the cutter, and pitting the surface before arriving at the place where the doffer is located. A powerful blast projected onto the right spot should drive the chips away, but they would be scattered so that it would be difficult to collect them.

675. Q.—What feed per revolution would you recommend for 12-inch or 18-inch width of cut on yellow pine, 44 inches to 54 inches saw and 20 horse-power engine?

A.—Probably from ⅛ inch to ¼ inch. If you can see any saw doing that anywhere, you can learn more from that than you can from us.

Foundry.

676. Q.—Should a cupola have any taper?

A.—The taper to a cupola is of no perceptible benefit, when relining is taken into consideration.

677. Q.—How high and how large should the tuyeres be for a small cupola?

A.—The tuyeres should be from 15 to 30 inches above the sand bottom, the higher the better the quality of iron melted. The size of tuyeres should be 33 per cent. larger than the outlet of fan. A large area of tuyeres relieves the fan.

678. Q.—What should be the pressure when charcoal is used?

A.—From 10 to 12 ounces in a 28-inch cupola will give the best results.

679. Q.—We use a high-speed fan; it gives a very strong blast. With charcoal our iron is very soft and strong, but at times the iron will not run, and it is impossible to fill a flask.

A.—The trouble may be in charging the cupola and in breaking the stock, which should be very small. Charcoal, if from hard wood, is nearly as durable as coke. The charging door may be too low.

680. Q.—Our cupola is charged every day with the same kind of coal, and no slag appears except when it is tapped out too large, then it shows great quantities. What is the cause?

A.—L. C. Jewett says: "The slag is there the same whether the hole is large or small. The reason why it is seen when the hole is large is because the large hole is higher in the breast and the iron gets below the top of the hole, so that the slag, which is always above the melted iron, flows out. I have practiced, in order to purge a cupola of slag in long heats, the following: Draw down as low as possible with regular tapping hole, then take away the ladle without stopping up, punch a large hole in the breast and let the slag out. Then stop up and go on as usual."

681. Q.—I placed a pressure gage on the wind-box of a cupola in the

Ottumwa Iron Works. When we started the fan the water fell 6 inches on one side and raised 6 inches on the other. The foreman claims that there is only a pressure due to the 6-inch rise, and I claim that there is a pressure due to the 12-inch rise. Who is right?

A.—The difference between the water level on one side and the water level on the other side of the gage is 12 inches, and therefore there must be a pressure which supports a column 12 inches high, hence your gage indicates a pressure due to the 12-inch rise. Assuming a cubic inch of water to weigh 0.036 pound, the gage indicates a pressure of $12 \times 0.036 = 0.432$ pound. To reduce this pressure to ounces, multiply 0.432 by 16, the product will be the number of ounces; thus, $0.432 \times 16 = 6.91$ or very near 7 ounces.

682. Q.—We use a Colliau cupola 27 inches diameter inside of lining, and charge 450 pounds of coke and 2,000 of iron on the bed. Thereafter we charge 50 pounds of coke to each 1,000 pounds of iron in each charge. After we tap the cupola two or three times we find that the iron gradually gets cooler after that. How could this be remedied?

A.—One cause of trouble with the cupola referred to is that people will too often try to follow the formula given by the makers of it in cases where the formula does not apply. It has been said by one foundryman that the best thing to do with the formula is to put it in the cupola with the first charge and then experiment to determine the best methods of charging for the conditions. In this case nothing seems likely to be helpful except experiments, and we should suggest in this case first to try the bed of fuel, say, 24 or 28 inches above the top of lower tuyere. 2d. Reduce the first charge of iron to, say, 1,800 pounds. 3d. Increase the first charge of coke to about 60 or 70 pounds. 4th. Reduce the next charge of iron to about 800 pounds. The last two or three charges could be increased to 1,000 pounds of iron, as when the cupola gets warmed up it will do more work. If this heat charged as above comes slow and the iron is extremely hot, then reduce the bed two or three inches. If it continues to work evenly through the heat it is evident that everything is all right, but if the iron gets hotter as the heat progresses, then reduce the subsequent charges of

coke. The whole secret of melting may be summed up in finding the point where the bed has the best combustion, and then keeping it there. And the best way is to conduct experiments, three or four heats being usually sufficient to show the best method of charging for any given set of conditions.

683. Q.—We have experienced considerable trouble from the fire-brick melting in our cupola. Our foundry foreman insists upon mixing the fire-clay with salt every time he relines it, and it is our belief that this may have something to do with the conversion of the brick into a stringy slag under the intense heat. Is it necessary to use salt for such work?

A.—Mr. Simpson Bolland replies to this as follows: "Regarding the use of salt to mix with sand for furnace lining, or with the clay for building purposes in the cupola. I think this bad practice may have originated in a misconception of its right use in the stone and earthenware manufactories, where salt is extensively employed as a glazing agent, its fusibility at furnace heat combining with other qualities to fit it for this use. No doubt it has been thought by those who were only partially instructed in these things that a permanent glaze similar to that produced on the earthenware might be given the cupola by the use of salt; but, if they will remember that salt fuses at a red heat they will at once realize that any salt used for cupola purposes must constitute a slag-forming agent at every heat, until every vestige of salt has been melted out."

684. Q.—Our cupola burns out in about eight heats; that is, when we have cast eight times we are obliged to reline with fire-brick. Our fan is 24 inches diameter with four vanes 8x8 inches, and set almost straight out from the center, with discharge pipe from fan of 8 inches diameter, which runs to back of cupola, and then the blast is carried into the cupola by two tuyeres set opposite each other, and 15 inches above the bottom of the plate. The cupola is made straight on the inside, and is 22 inches diameter in the clear when newly lined. Now, we know of other cupolas which run six or eight months, and still longer, without relining. We have good fire-brick and clay. It takes from 1 to 1½ hours to melt from 20 to 25 hundred pounds of iron. Do we need more blasts and more tuyeres?

A.—Mr. S. Bolland replies as follows: "There are not suf-

ficient data given to enable me to answer the questions direct; I therefore give what I believe to be the correct particulars for working a 22-inch cupola, so far as blast, blast pipes and tuyeres are concerned. In the first place, from 1,200 to 1,800 pounds per hour is very favorable melting in a 22-inch cupola; more frequently the former is obtained, so it seems that the cupola in question is overworked, with the result as stated. For such a cupola, 324 cubic feet of air is required per minute, requiring a No. 1 pressure blower or its equivalent. Blast pipes should be 6½ inches diameter for 100 feet of travel, and 8½ inches for 300 feet. The number of tuyeres and size should be two of 5 inches diameter, or three of 3½ inches diameter. Blast pressure should be from 4 to 5 ounces, and hight of charging door about 9 feet. Such a cupola, if carefully worked, should melt from 3 to 4 tons."

685. Q.—What is a good pickling solution for sheet steel and castings?

A.—For cleaning castings, use 1 part of sulphuric acid and 10 parts of water. The vessel which holds this solution should be lined with sheet lead. The same solution is often used for steel, and may answer your purpose; we should advise you to try it before using it to any extent. Cast iron should receive considerable attention after pickling if it is intended to plate or japan it. The gray accumulation seen on the surface after the pickling will, if left thereon, be sure to fall off in time, bringing with it whatever has been subsequently applied. Simple water is not sufficient to accomplish a thorough cleaning from this objectionable film; the castings should be first steeped in a strong hot potash or soda bath, after which hot water or steam may be played over them until they are thoroughly clean, when after being heat dried they are ready for the plating, japanning or paint. In rolling mills, after pickling in the above solution, the bars are dipped in lime water and then dried.

686. Q.—In what does green molding sand differ from loam? Where is it from? What is its value? And what kind of castings are made in it?

A.—The terms "green sand" and "loam" have exclusive reference to mixtures and physical conditions; none whatever to geological character or to locality. Sand is "green" when the mixture is used in its natural condition, that is, damp or mixed

with just sufficient water to render it coherent. Immediately after the pattern is withdrawn therefrom the mold is ready, except for the necessary cleaning and mending up, and blackening to receive the metal. Loam is composed of dry sands and manure, and, instead of being rammed like the green sand, it is wrought up wet, similarly to mortar, being either struck or swept up with boards, or daubed around patterns or sections of patterns. The character of the casting to be made will decide whether green sand or loam molds are to be used. The sands suitable for all these mixtures can be obtained in almost any section of the country, some of course being much better than others.

687. Q.—Is there a rule for finding the weight of brass and iron castings by weighing the patterns, which are made of white pine?

A.—Multiply the weight of the pattern in pounds by 19, the product will be the weight in pounds of the brass casting. For cast iron, multiply the weight of the pattern by 16.7.

688. Q.—We have several tons of gas retorts we want to melt with other scrap. Before melting they appear soft, but after melting with other iron they make very hard castings. Is there anything in the making of coal gas that causes the hardness of the iron? Will old retorts make soft castings by mixing with any brand of pig iron?

A.—W. J. Keep, of Detroit, answers this as follows: "The iron from gas retorts may have absorbed sulphur from the coal from which gas was made. In any case, by mixing sufficient silvery iron the castings will be gray and soft. Any iron broker will sell Ohio or Southern silvery pig iron, or there may be a silvery iron made at a nearer point. Add, as a trial, 25 per cent. silvery iron to 75 per cent. gas retorts; if too soft, use less, or *vice versa.*"

689. Q.—We have a contract to furnish a great many pipes (cast iron). The dimensions are: Outside diameter, 4 inches; inside diameter, 3⅜ inches; length, 9 feet. The pipes must stand 150 pounds water pressure, must be free from swells or other projections on the outside, as a scraper fitting the pipe must slide up and down. Where they are now made, they are cast on end, but complaint is made of their being swelled at the lower end. I would like to know how these pipes are poured on end, whether

from the top or bottom, and if the molds are of dry or green sand with skin-dried surface, or are they cast in an ordinary mold. My idea is to incline the flask from 12 to 15 inches in its length, having a runner and riser (runner at lowest part) to about equalize one another, and have two in a flask. Would it be necessary to have a pan to dry the cores in the mold or would a straight plate and black sand be sufficient?

A.—S. Bolland replies as follows: "In regular pipe foundries, plain straight pipes of the dimensions given are usually rammed in casings vertically, thoroughly dried, and cast from the top in the same position. When such pipes are swelled at the bottom, it is owing to the fact that the molds were only partially dried, or perhaps cast green. While the vertical dry sand method is to be preferred always, it is possible to make sound pipes free from swells in green sand, if no less than 18 inches of incline be given to the flasks, the molds well rammed and most, if not all, of the iron poured from the upper end. To pour all the iron from the bottom would force the dullest metal to the part of least pressure, something always to be avoided by all means possible. The quickest method of molding such pipes in a horizontal position, either one or two in a flask, would be to withdraw a turned iron pattern, or patterns, through a fixed match plate, using the plate for both cope and nowel. Cores on perforated tubes are to be preferred for all such work when it is desired to produce exact bores. But if for any reason dry-sand cores must be used, then in this particular case provide pans to insure a true circle free from fins in the bore."

690. Q.—S. asks for instructions for fusing cast iron on cast steel.

A.—It is necessary that the steel where it is to come in contact with the iron shall be perfectly clean, and in order to protect this face it is necessary to give it a coat of tin. It is possible, also, that this tin assists the operation of welding by forming a low-melting alloy. Where the bulk of the steel is small compared with that of the iron, the heat of the molten iron is enough to form a good weld if the mold is so arranged that the iron flows over the steel while filling the mold. but if the iron body is small compared with the steel, enough iron must be flowed through the mold and run to waste to give heat enough to make the weld.

691. Q.—How can I successfully cast an anvil about 18 inches long, 12 inches wide, and 7 or 8 inches thick, chilled on the top surface? It will be necessary to grind these smooth after chilling, so that the surface must be solid, and it should be chilled in, probably 1 inch at least.

A.—To cast such an anvil block, let the face side be cast downwards upon a chill, made of good, strong and close cast iron in which the carbon is largely combined. This chill ought to be at least 6 inches thick, and the face side should be finished smooth and rubbed over with blacklead having a slight mixture of oil before the mold is cast. Use car-wheel scrap, such as shows a deep chill on the tread, or obtain No. 3 iron, containing about 2 per cent. carbon, that is slightly mottled and shows a bright gray fracture with very fine grains. The addition of scrap steel or spiegeleisen increases the depth of chill.

692. Q.—A number of castings have the appearance of malleable iron, but are claimed by the makers to be cast steel. What chemical or physical test will settle the matter?

A.—Anyone familiar with malleable iron can recognize it by the fracture. When broken it will show a skin of more or less thickness of fine grain, and quite white, while the interior will be of quite a dark color and more or less rotten in appearance. A steel casting when broken will show a practically uniform granulation over the whole surface. The steel casting looks like steel in the fracture, while malleable iron decidedly does not.

693. Q.—What is the melting point of aluminum?

A.—We have various figures for this from different authorities ranging all the way from 1,100 degrees to 1,400 degrees Fahr. Aluminum melts quite slowly and cannot be rushed, which has made it difficult to determine the melting point with precision. Pure aluminum is also rarely melted, more or less alloy being usually present and varying the melting point.

694. Q.—What is the proper heat to melt aluminum, and can it be cast in ordinary molds, the same as other metals? Have been in the brass foundry business twenty-five years.

A.—The melting point of aluminum is 1,157 degrees Fahr., that of zinc being about 700 degrees, and copper about 1,930 degrees. It melts very slowly, and cannot be crowded. It

should not be much overheated. It may be melted in the ordinary plumbago crucible, and the metal need not be covered. Either iron or sand molds may be used. With iron molds, although they are largely used, the metal is quite apt to blow unless special precautions are taken. The sand should be loose and open, and a large gate and high riser should be used.

695. Q.—Why does a big gate on aluminum castings make a hollow or draw greater than a small gate? The difference is so great the molders are at a loss what to do in gating aluminum castings. Castings and gates drawing with big gates cut on them are contrary to the laws of molding and the nature of the metal.

A.—Mr. James McGuire, New York representative of the Pittsburgh Reduction Company, replies as follows: "In regard to a large gate on aluminum castings making a greater hollow or draw than a small gate, in the case of the large gate the shrinkage is mostly in the gate; in the use of the small gate the shrinkage is distributed more throughout the casting, the total amount of shrinkage in the case of the small gate being not as perceptible as when using a large gate; in the former case, it is not in any one place, but more distributed. Aluminum castings should be made with as large and as high a gate as possible, in order that the shrinkage may be all in the gate. In using a large and high gate you have a greater head to your metal when in the liquid state, thereby forcing it to distant parts of the mold and getting a more perfect casting than you otherwise would. Aluminum melts at about 1,160 degrees Fahr. It should be poured as near this temperature as is practicable. After taking the metal off the fire it should be cooled down with some ingot aluminum in order to reduce the temperature as near to 1,160 degrees before pouring as possible. It is particularly desirable that in melting aluminum, especially alloys of aluminum, the temperature should not be raised any more above the melting point than is absolutely necessary, the plumbago crucible being the best form of crucible to use in melting aluminum, and sand molds the best molds for casting."

696. Q.—What are the properties of a gas generated from burning sand by molten iron, and its explosive power?

A.—The molds and cores contain various proportions of organic and volatile matters, consisting of portions

of roots, horse dung, coal, straw, etc., all of which when decomposed by the hot metal generate inflammable gases; in addition to which must be added steam from the moist sand, which gives rise to hydrogen, while its oxygen combines with whatever carbon may be present in the material to form carbonic oxides. These inflammable gases when mixed with air produce a dangerously explosive compound. From the above it will be seen that the gases depend on the substances which enter into the mold, and little can be said of their explosive powers, but that they do explode with terrific force has been proven by sad experiences. It is in dealing with this objectionable compound that the molder's judgment and skill are frequently taxed to the utmost in order to avoid terrible consequences.

697. Q.—In making grinders for corn-mills of cast iron in small quantities, which is the best process of hardening the iron in the ladle? What mixture of pig iron will be best to make castings that will break white for such purposes as bells, plow points and grinders for corn-mills?

A.—W. J. Keep says: "To produce a chilling iron the silicon must be kept lower than is desirable for machinery castings. In the charges that are to be put into chilled castings leave out the soft irons. You can procure irons made from Lake Superior ore that will be more likely to give a chill. It is probable that you make the castings you name, with hard surface, against an iron chill. Any iron with low silicon will produce a chilled surface if run against an iron mold. A piece of ferro-manganese the size of an egg, or, better, in small pieces, placed in a 50-pound ladle before being filled with iron will harden the chilled surface."

698. Q.—Is there any mixture of sand or any preparation with which to coat dry-sand cores to keep them from getting damp after being placed in the mold?

A.—Mix thoroughly when dry half river sand and half fire sand, sift through a fine sieve; then to 15 parts of mixed sands add 1 part of resin, ½ part of flour, and mix with weak molasses water. One part of sawdust may be added to 10 parts of the mixed sands. This addition will be required only when the cores must lie in the molds several days.

699. Q.—We are building twenty crucible furnaces for melting copper

in our brass foundry; what should be the internal area at the base and top, also thickness of walls, and is there any law governing the hight of chimneys for this work?

A.—We should build a square chimney with a straight lining. The inner cross-sectional area should be one-eighth of the total grate surface of the furnaces, and the hight not over eight times the outer breadth. The outer batter should be ⅜ inch per foot. The lining should be 4 inches thick; if 30 feet in hight or over, the outer wall should be 8 inches thick. The lining should run to within a foot or two of the top of the outer wall, and they should touch each other there, leaving at the bottom a space between the two walls equal to the total batter, or nearly so.

700. Q.—How are car journal brasses lined with lead in large brass foundries that make lead-lined journal brasses for railroad cars?

A.—There are two ways of lining brasses with lead . First, sometimes brasses are lined with sheet lead (this manner of lining them is patented); second, the lead is cast on to the brass, and on this process there is no patent. This is accomplished in the following manner: The concave surface is first coated with a thin coat of tin. To do this the brass must be carefully cleaned and care be taken that no grease spots are left; it makes no difference whether the brass be cleaned mechanically or chemically. In brass foundries the brasses are generally cleaned by dipping them while warm in muriatic acid; after this the surface is tinned. The object of the tinning is to make the lead stick. After the brasses are tinned they are placed near a mandrel of the required size; the space between the mandrel and the surface which is to be lined with lead must be equal to the required thickness of the lead; the lead is then poured between the mandrel and the brass.

701. Q.—Can you tell me how to tin chaplets, anchors, etc.?

A.—You must first remove the scale so as to get a clean surface. If of cast iron this can be done on an emery wheel. If of wrought iron they can be ground clean or immersed in a solution of sulphuric acid and water, then scoured and washed with pure water. Then heat hot enough to melt tin, sprinkle over with sal-ammoniac and apply the tin, wiping off the surplus. If doing in large quantities, the tin can be melted in a pot and the pieces dipped.

702. Q.—What is the correct and simple method of molders for measuring the capacity of ladles used?

A.—Different molders have different methods. Our method would be based on the fact that a cubic inch of iron weighs approximately ¼ of a pound; hence, by finding the capacity of the ladle in cubic inches, and dividing it by 4, an approximation near enough for practical purposes would be arrived at. For instance, to find the capacity of a ladle 2 feet diameter and 2 feet in depth inside the lining, the area of a 24-inch circle is (omitting fractions) 452 inches, which, multiplied by the depth (24 inches) gives 10,848 cubic inches capacity. This divided by 4 gives 2,712 as the capacity in pounds, or say a 2,500-pound ladle. If the sides of the ladle are not straight, the average diameter must be found.

703. Q.—What is the meaning of the term "chipping piece" applied to castings?

A.—A chipping piece or strip is simply a raised portion of the casting, put on for the purpose of enabling the workman to chip, file or plane a comparatively small surface in fitting up a machine.

704. Q.—What kind of wood is mostly used in making patterns, and with what are patterns painted, and how many coats?

A.—Patterns are usually made from white straight-grained pine, and receive a coat of varnish made from one pound of shellac dissolved in one gallon of alcohol, with as much lampblack as will color it. After this has thoroughly dried, the patterns are rubbed off with fine sandpaper and another coat of the varnish slightly diluted with alcohol applied. Sometimes the lampblack is not used in the varnish, which will then give the patterns a yellow finish.

705. Q.—We have a large number of iron patterns and are much troubled by their continued rusting when not in use. Can you suggest a remedy?

A.—We suppose you are familiar with the common method of finishing iron patterns, which consists in wetting their surfaces, after such finishing as is considered necessary, and thereby coating them with rust. They are then heated and beeswax melted over them and rubbed into the rust. Iron patterns treated in this way do not usually rust easily, if at all, and we know of no better method of preventing rust.

706. Q.—I had occasion to make a core-box 14 inches long and of a section like Fig. 1, for making two similar cores at once. B. claims that, on account of its being a double box, the two parallel sides *C* must have draft to allow the core to draw free, while A. claims that, owing to the 3-inch radius, the two sides *C* can be left perfectly square, and that there would still be plenty of draft for the core to drop out. Always allowing that a core-box should have draft, which of us is right?

A.—We assume that after the core is rammed up, the core and box will be turned over upon a plate and the box will be drawn from the core, rather than the core from the box. The extreme corner *a* of each core is of course parallel with its

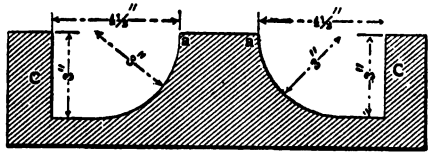


Fig. 1

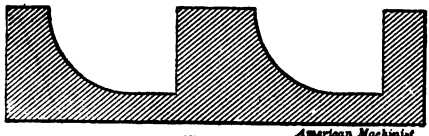


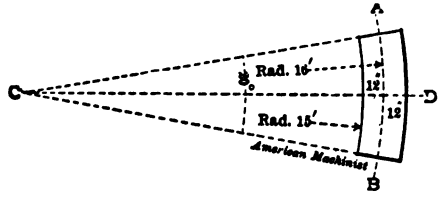
Fig. 2

side *C;* but these corners would not break, as they would be supported by the plate, and each core individually would have draft or clearance immediately after the drawing was begun. The two sides *C C,* however, of the two cores, being parallel with each other, would have no clearance relatively to each other, and such clearance could only occur by the sliding of one or both of the cores upon the plate. If the two cores were made in the box, as in Fig. 2, a slight lateral movement of the box after the drawing began would of course free both cores, and no draft would be required on the vertical sides.

707. Q.—Does the shrinkage contract iron (or other material) tangential to the arc *A B,* or at right angles to center line *C D?* Is it proper in laying out work for the patternmaker to allow.

in this case, shrinkage on 15-foot radius, or to lay out the 16 feet actual size and allow shrinkage each side of line *A B*? In one case the inside radius would be about 15 feet 2 inches, and in the other it would be 14 feet 11⅞ inches. Which, if either, is correct? Does the curvature of the segment accommodate itself to the proper radius after molding when shrinkage is taken into account on said radius?

A.—The matter is not as complicated or difficult as our correspondent seems to imagine. If he was dealing with a complete ring instead of a segment he would know of course that it would shrink in diameter at the regular rate of shrinkage. It is not different in any respect with the segment. It will shrink equally in all directions, precisely the same as if it were an integral part of a complete ring. The patternmaker merely works to a slightly larger scale, and all his measures should be



to that scale. The inner radius of the segement then, allowing ⅛ inch to the foot, would be 15 feet 1⅞ inches, the radius of the middle line *A B* of the rim would be 16 feet 2 inches and the radius of the outside of the rim would be 17 feet 2⅛ inches. The subsequent foundry experience with the pattern might perhaps seem to show that the theory in the case was not correct. The segment when cooled might prove to have perhaps more or perhaps less than the correct curvature, but this would not be the fault of the pattern. The cause would be rather in the gating of the mold, and much more in the uncovering of the hot casting and the precedence given to the different parts of it in cooling. It would probably be best to secure an equal rate of cooling for both the inner and the outer surfaces if possible.

708. Q.—What is the best mixture for a locomotive bell, and what is the usual weight?

A.—The usual weight is from 80 to 90 pounds. A common

mixture is 4 parts of copper to 1 part of tin, to which is added 17 ounces antimony, 4 ounces zinc, and, in some instances, 2 parts of lead.

709. Q.—What is the composition of the alloy for steam cocks, valves, etc.?

A.—The following we believe to be a good composition for brass castings subjected to steam pressure: 20 pounds of copper, 1½ pounds of tin, 1 pound of lead, and 1 pound of zinc.

710. Q.—What proportion of metals is suitable for chandelier work, also what for a soft valve mixture, same as used for steam and water?

A.—For chandelier work, use from 8 to 10 ounces of zinc to 1 pound of copper. For valves, or all castings subjected to a steam pressure, use 20 pounds of copper, 1½ pounds of tin, 1 pound of lead, and 1 pound of zinc.

711. Q.—What mixture or alloy is good for thin open-work castings? They are to be used for ornamental work of 9 inches square and 1-16 to ⅛ inch thick. The alloy should be pretty hard, so that it can be easily silver-plated, but it should not be too brittle. It should flow easily into brass molds, and should not require too high a temperature for melting, and should not cost more than 8 cents a pound.

A.—Four parts of lead and two parts of antimony by weight may answer your purpose.

712. Q.—What mixture is best for a good hard brass, something suitable for an engine of 175 horse-power, driving two large band-saws? The brasses are to be used on the crank-pin, 6⅜ inches diameter and about 5 inches in length. We cannot make a brass that will stand up to the work. The crank-pin is perfectly round and smooth, and the engine is in line.

A.—We should use 6 pounds of copper and 1 pound of tin and to 100 pounds of this mixture we would add ½ pound of zinc and ½ pound of lead. The brasses made from this mixture should be recessed to receive babbitt metal. If this does not overcome the trouble, then the probability is that the crank-pin is too small for the work it has to do.

713. Q.—Has steam heat been tried for baking foundry cores, and if so, with what success?

A.—There are numbers of steam-heated ovens in this country,

and I rather think we are to some extent indebted to Europe for this idea, which consists simply of piping direct from the boiler to the oven, where a valve controls the amount of steam allowed to enter a system of coils, which latter constitute the core shelves as well, being set somewhat slanting for drainage. Sixty pounds gage pressure in the coils gives a temperature of 250 degrees, which will dry ordinary cores without the possibility of burning them; an increased pressure will, of course, give greater heat. Ventilation is perhaps best secured by a somewhat loose-fitting door, and an outlet at the bottom of the wall. (S. Bolland.)

714. Q.—What is the best formula for a dipping solution for cleaning and brightening brass castings?

A.—We suppose you want a solution for cleaning new brass castings as they come from the foundry. Make a solution of 2 parts of water, 2 of sulphuric acid, and 1 of nitric acid. Mix these as follows: First mix the water and sulphuric acid, and let these cool; then add the nitric acid; when this solution is cool, it will be ready for use. Dip the castings which are to be cleaned in the solution, and withdraw them quickly; repeat this operation until the castings are bright; rinse in cold water, then in hot water, and finally throw them in sawdust to dry.

715. Q.—What is the process of pickling brass castings, such as oil cups, pump boxes, injectors, etc.?

A.—Mr. Abram Ammerman, superintendent of the Jackson Architectural Iron Works, New York, informs us that the mixture used at that establishment is: 2 parts by measure of nitric acid and 3 parts sulphuric acid, with a handful of table salt to each quart, and no water. The pickle may be held in any suitable receptacle, say, of glazed earthenware, or a vitrified bathtub might do, although it is only necessary to provide a vessel large enough for the immersion of the largest piece to be handled. The pieces are simply dipped in and removed at once and rinsed in clear water. This is merely for cleaning and brightening the castings. Various dips are used for giving different colors.

716. Q.—We have to cast the lead keel of a yacht to weigh 5,000 pounds. Can you tell how to melt the lead without building a furnace?

A.—It will not require a very large foundry ladle to hold 5,000 pounds of lead, and you can construct a temporary brick setting, using stovepipe to get draft. If one ladle is not large enough, use two or more.

717. Q.—Please give me a method for melting brass in a small ladle without a brass furnace.

A.—To melt brass in a ladle is a very unsatisfactory way of doing it, because the ladle is liable to burn out before the brass is melted. If it is necessary to melt a small quantity of brass without placing it in the furnace, we should advise you to procure a small crucible and melt the brass in it over a blacksmith's fire.

718. Q.—In casting journal brasses in the drag, the brasses don't come sound. It does not show until I bore them, and I find that there are small holes, so I have been making them in the cope; is there any way to overcome this?

A.—Mr. L. C. Jewett answers as follows: "The trouble is due to wet sand or very close sand. Sand for brass work cannot be used as damp as for iron, for when the brass or composition touches the sand, a thick film, or skin, as the foundryman calls it, is formed, and if bubbles of steam occur, they are imprisoned under the skin. Sand should be used as dry as possible and be thoroughly or evenly tempered or moistened. It should be rammed firmly, swabbed as lightly as possible, metal poured at low heat for journal boxes, and success should follow. To make assurance doubly sure, blow molasses water or sour beer on the mold, then skin dry."

719. Q.—How is phosphor bronze made?

A.—Ordinary phosphor bronze consists simply of any alloy of bronze, or any ternary alloy of copper, tin and zinc which has been given exceptional purity and excellence by skillful fluxing with phosphorus. It is also supposed that the presence of phosphorus is useful in giving the tin a crystalline character, which enables it to alloy itself more completely and strongly with the copper. The amount of phosphorus in an alloy depends on the purposes for which the phosphor bronze is to be used. The minimum and maximum percentages of phosphorus in phosphor bronze are 2 and 4. Five sorts of phosphor bronze, however, are considered to answer all requirements:

0. Ordinary phosphor bronze of 2 per cent. of phosphorus. 1. Good phosphor bronze of 2½ per cent. of phosphorus. These two numbers are superior to ordinary bronze and steel in all cases. 2. Superior phosphor bronze of 3 per cent. of phosphorus. 3. Extra phosphor bronze of 3½ per cent. of phosphorus. 4. Maximum phosphor bronze of 4 per cent. of phosphorus. In making phosphor bronze, or copper alloy of all sorts, the copper should first be melted in the usual way, with a cover of charcoal put over it as quickly as possible. After the required quantities of tin, zinc, etc., have been added, or, in case of gun metal or brass scrap, after the latter has been completely melted, the small exactly weighed quantity of phosphor is added, while the metal is continually stirred. For stirring, a graphite bar, a strip cut from an old plumbago crucible, or a bar of retort carbon, should be used. The stirring has to be done carefully, and the metal then freed of the coal and scoriæ floating on the top; it should be poured before the surface begins to be covered with a skin. The latter point and the careful stirring cannot be too urgently recommended. See "Materials of Engineering," Part III., by Robert H. Thurston, from which the foregoing has been taken.

720. Q.—Is there anything besides sand that brass can be molded in? How can we get brass of a light color when taken from the sand? Is it at all possible to get a cylinder clean without having a lot of sand holes on top when it is faced up?

A.—L. C. Jewett replies to these queries as follows: "Brass can be cast in iron molds if the casting is of such shape as not to bind in shrinking. Brass can be made bright by dipping in acid, as for example equal parts of sulphuric acid, nitric acid and water. A little muriatic acid helps it. To clean brass for dipping, remove all sand and keep from grease or oil. It is better to rumble the brass in a wooden barrel immersed in water after the sand is removed; then dip in the acid, immersing for 30 seconds, then work in clean water and dry in sawdust. A sound cylinder, brass or iron, is obtained by having a well-vented mold and core, clean metal, well skimmed and poured warm."

721. Q.—We are having much trouble with our bronze. We use largely old bronze supposed to be about 1 tin to 16 copper, with the addition of a very little phosphorus. Nearly all our castings

are full of small clean holes, sometimes the castings are perfectly honeycombed.

A.—The old metal should never be used alone, not more than one-third of a mixture should be old metal. An alloy of 1 tin to 16 copper, without a trace of lead in it, is very difficult to pour; an addition of 1 per cent. of lead and 1 per cent. of zinc will be an improvement. Great care is required in melting phosphor bronze, and when it has the proper temperature for pouring it should be used at once. Sand which is too fine and wet molds will give imperfect results.

722. Q.—What should be mixed with old brass to make it mold easily and soft enough to work? I have a quantity of old brass, mostly globe valves and steam fittings, and want to cast them into connecting-rod brasses, gibs, etc. Also what is best to make the molds of? I want smooth, bright castings, and not too white.

A.—You cannot get first-class rod brasses and gibs from the kind of material you speak of, and what it would be necessary to put with it to improve the quality will depend upon the quality of the old brass. A good brass molder would know by inspection about what was needed, and our advice is to employ one; it will be the only satisfactory way. Sand is used for the molds.

723. Q.—I have a quantity of sheet brass which I desire to make into small castings, but cannot get good results; can you tell me what to do?

A.—The molds should be well dried with hot plates or in an oven. This is essential with fine brass, as the steam oxydizes the zinc, and the oxide fills the finer interstices of the mold. The molds should be poured on end, the metal should be hot and the sprues choked while pouring. If the above treatment does not produce the desired results, try adding phosphor tin or antimony, which will increase fluidity and hardness. One or two trials will serve to determine the required quantity. Two per cent. will make a marked difference. If too much is used it will injure the color. For fine furniture trimmings and such castings, the finest of sand must of course be used, and then fine scratches on the joint of the mold and sometimes small vents with wire in the delicate points will allow the air to escape that would otherwise be imprisoned and prevent the metal from flowing into and filling these interstices.

Blacksmith.

724. Q.—What blast pressures are recommended for railway-shop blacksmith fires and similar machine-shop work?

A.—We would recommend a pressure of .25 to .3 pounds per square inch?

725. Q.—In taking off an old tire by heating it by means of perforated pipes placed around the tire, encased by sheet-iron covers, does the heat affect the centers enough to produce an error in making a fit with a new tire—I mean taking the size of center immediately after the old tire has been taken off?

A.—The heat will of course affect the center; we should never measure it before it has been thoroughly cooled.

726. Q.—Of what are tool steel and cast iron composed, and which contains most carbon?

A.—No complete and specific answer can be given to this question. If iron is pure, it is composed of nothing but iron. It is never found absolutely pure, however, and most American cast irons contain carbon, silicon, phosphorus, manganese and sulphur. The proportions of these vary very much in different specimens. Silicon sometimes goes as high as .6 per cent. or more. The other impurities are usually less; but carbon usually goes above .3 per cent., and .5 per cent. of carbon is not uncommon. Steel may also contain small quantities of silicon, manganese, sulphur and phosphorus; though the last two are objectionable and good steel contains them in very small proportions, or is practically free from them. Steel contains from 1 to 1.5 per cent. of carbon, and the most generally useful steel for tools about 1 per cent.

727. Q.—What is the difference between machinery steel and Bessemer steel, and is cold-rolled steel made from both?

A.—Machinery steel is a special name given to Bessemer steel which is made with special reference to the requirements of machine constructors, and machinery steel is Bessemer, though Bessemer steel is not necessarily machinery steel. Ma-

chinery steel is usually so low in carbon that it will not harden by the ordinary methods for hardening steel. Cold-rolled steel, we believe, is made from low-carbon, soft Bessemer steel.

728. Q.—What is the proper method of annealing brass tubes previous to placing them in the tube sheet?

A.—One method is to heat the tubes and then plunge them in water. Another method is to heat the tubes in a furnace specially built for the purpose, and then let them cool gradually in the furnace. Either method will anneal the flues; the first one will answer when the work is wanted in a hurry, the second is the best and safest one.

729. Q.—Which is best for bending, square steel or round steel, of equal cross-sectional area? The bends are to be at right angles, like bicycle cranks.

A.—The round steel will be best for the purpose.

730. Q.—Why will iron burn in a blacksmith's fire instead of melting, and why does it not do the same in a cupola?

A.—Iron burns to a certain extent when it comes from a cupola into the air, as may be noticed when the tap hole is open at the time the iron begins to come down. The iron does not fly off in burning sparks until it comes into such a position that it is blown into small particles by the blast. Then it is in such a condition that it can unite very fast with the oxygen of the atmosphere, and the vivid sparks fly off. In a smith's fire there is but a small body of iron exposed to the action of the fire. and the moment a part of it becomes melted it is seized by the blast which comes from below, and very quickly unites with oxygen. If, in the smith's fire, we bring in the blast in such a position and quantity that the iron is sufficiently heated without coming in contact with an excess of oxygen under comparatively high pressure, then we can successfully melt, without burning, a piece of iron in a blacksmith's fire.

731. Q.—How do you work Mushet steel?

A.—Forge as in ordinary working cast steel, but be very careful not to heat hotter than a dull red. After the tool is shaped, lay it down to cool without hardening or tempering. When cold, grind and use.

732. Q.—A claims that the temper of a Mushet steel tool can be drawn by grinding on a dry emery wheel. B claims it cannot unless

water is allowed to touch the steel while it is hot. Which is right?

A.—Strictly speaking, it is not possible to draw the temper of Mushet steel either by dry or wet grinding, or in any other way, for much the same reason that blood cannot be drawn from a turnip. Mushet steel has no "temper," and, moreover, it is not really steel, though it goes by that name. It is an alloy, and its natural condition is to be hard, or, in other words, it is simply a hard alloy of iron. The makers of the "Crescent" hardened steel, which is practically the same as Mushet's, recommend that after the tool has been forged its point be heated to a bright red and allowed to cool in the air away from water. The usual effect of water upon the steel when it is hot is to crack it, and sometimes to cause it to fly to pieces; and, so far as known, this is all the effect produced upon it by water, and even this is not produced, of course, unless the steel be red-hot. It is found in practice that if the tools are ground upon a dry emery wheel, and at the last pressed hard upon it, so that they become red-hot, and then allowed to cool in the air, they are improved. It is possible that in grinding the extreme cutting edge may become red-hot, and then if water comes into contact with it at that time, fine cracks extending through the small portion of the tool which has been heated may make the extreme edge crumble off in service, from which it might be supposed that the temper had been drawn.

733. Q.—Is it possible to weld Mushet or other self-hardening steel?

A.—It is impossible to weld self-hardening steel with the hammer, as when heated hot enough it goes to pieces. It can, however, be welded to iron under a press. The iron should be heated to a good high heat, and the self-hardening steel to about a yellow or good forging heat. Nail-cutting knives have been made in this way and have done good work.

734. Q.—I have an anvil which weighs about 200 pounds; its face has been hammered until it has become sunken and its edges broken off. I want to know if the temper can be drawn, the face planed, and then tempered without incurring much expense. The tempering, in my opinion, is the most difficult part. How should I go about it?

A.—To draw the temper, heat the anvil to a cherry red and

then let it cool slowly; then plane off or dress the face, as desired. To temper the face, heat it to a cherry red, and then place the anvil with its face up in a tank filled with water; the depth of the tank should be such that the water in it will just cover the face of the anvil, then play water upon it by means of a hose, until the face is cool. If there is a waterfall near you, the face of the anvil can be tempered by simply placing the anvil after its face has been heated underneath the fall. The expense of dressing and tempering the face as above described should not be very great.

735. Q.—Can steel castings be softened for working up and then hardened through and through; also, can drop forgings be treated in the same way?

A.—Steel castings are generally annealed before they leave the foundry, and if these are not soft enough for working it is doubtful whether you can improve them. The degree of hardness to which steel castings and steel drop forgings can be brought will depend on the proportion of carbon in the steel. Forgings which are comparatively thin, say, one-eighth inch thick, can practically be hardened through and through.

736. Q.—Can Mushet steel be annealed so that it can be turned and milled; if so, how can it be done?

A.—B. M. Jones & Co., sole representatives of this steel in this country, reply as follows: "R. Mushet's special steel can be annealed with facility by any person of common intelligence in such like things by following closely the accompanying directions which we are at all times glad to furnish. When properly annealed, it may be made into milling cutters, taps and a variety of uses. Many other processes of annealing Mushet's steel have been suggested and offered to us from time to time, but we believe the following is thoroughly reliable: After the steel is forged, heat it up thoroughly to a light yellow (short of burning) and bury it in hot ashes from the smithy fire or in lime, and cover over with fine ashes or sawdust, so as to exclude the air thoroughly till perfectly cold. The steel will then be annealed for turning, filing, etc., but if it is found to be hard below the surface when cut into for working, it may be necessary to anneal again before finishing."

737. Q.—Which is the front side of an anvil—the side on which the smith works or the side on which the helper works?

A.—B. F. Spalding replies as follows: "I would say that I have never heard it doubted that the side toward the helper is the front side. There is an analogy between the smith's forge, tool bench and anvil. If he stands in front of his forge and tool bench, how is it that he is not also in front of his anvil? I think, however, that it is generally conceded that the 'front' side of an object is the side facing the direction from which visitors approach; it is so with a carpenter's bench, a machinist's lathe, a sample-room bar, a dry-goods counter, etc. The front side is not the side toward the party who stays, but the side toward the party who comes. As visitors approach an anvil from the helper's side that makes this side the front one."

738. Q.—What degree of temperature is iron when it has a dark-red color?

A.—Much depends on the eyes of the observer as to when he will begin to see red heat. It is usually said, however, that iron begins to be visibly red in the dark at about 700 degrees Fahr. The following is the table constructed by Mr. Pouillet, and which is generally accepted:

	Deg. F.
Incipient red heat	977
Dull red heat	1,292
Incipient cherry red	1,472
Cherry red	1,652
Clear cherry red	1,832
Deep orange	2,021
Clear orange	2,192
White heat	2,372
Bright white	2,552
Dazzling white	2,732 to 2,912

In connection with this, the following table of temper colors and temperature is interesting. A bar of bright iron or steel, slowly heated in contact with air, assumes the following tints at the temperatures given:

	Deg. F.
Deep orange	421
Orange	473
Red	509
Violet	531
Indigo	550
Blue	559
Green	630
Oxide gray	752

739. Q.—How much of a blow is a blacksmith's helper capable of striking with an 18-pound sledge?

A.—The force of a blow cannot be properly stated in the manner suggested. Perhaps the best way to treat the matter will be to make the case more definite. Say that the sledge is raised and descends at each blow 4 feet, and that it strikes upon hot iron, making an indentation one-tenth of an inch deep, or that the descent of the sledge is entirely arrested in the space of one-tenth of an inch. We may first compute the velocity and force of the descent of the sledge, supposing it to be acted upon by gravity alone. The formula for the velocity is: $v = \sqrt{2 \times a \times s}$, in which v is the velocity in feet per second after falling the given distance, a the acceleration due to gravity, say 32 feet per second, and s the hight of the vertical distance traversed in the fall. Substituting our values, we have: $v = \sqrt{2 \times 32 \times 4} = 16$ feet per second. The formula for the energy acquired is $E = \frac{W \times v^2}{64.4}$, E being the stored-up energy in foot-pounds, W the weight in pounds, and v the acquired velocity. Substituting our values, we have: $E = \frac{18 \times 16^2}{64.4}$ $= 71.55$ foot-pounds. The force contributed by the helper cannot very well be determined. If we assume that the man was able to exert a force upon the descending sledge equal to that of gravity, then the total energy would be $71.55 \times 2 = 143.1$ foot-pounds, and as the descent was arrested in the space of .1 inch, the average resistance by which the sledge was stopped, or the average force of the blow, was $143.1 \div .1 = 1{,}431$ pounds

If the sledge had been stopped in the space of a hundredth of an inch, instead of a tenth, then the average force for the same blow would have been 14,310 pounds, so that the distance in which the stoppage is effected is quite as important a factor as the distance through which the force is applied.

740. Q.—What is the rating of a steam hammer with a cylinder 6 inches diameter and steam at 60 pounds pressure?

A.—There is no customary "rating" for steam hammers; they are usually designated by the weight of the ram or "tup" plus the steam pressure, if any; but sometimes, very irrelevantly, by the total weight of the hammer apparatus.

741. Q.—When the steel maker speaks of steel 5 to 7 points carbon, does he mean 5 to 7 one-hundredths of 1 per cent., or 5 to 7 per cent.?

A.—Each point of carbon in steel is one-hundredth of 1 per cent.

742. Q.—What is the ordinary proportion of carbon in open-hearth steel tires for car wheels?

A.—Such steel usually runs from 0.60 to 0.70 carbon, and will have, approximately, 115,000 pounds per square inch tensile strength, with an elongation of 14 per cent. in 4 inches.

743. Q.—I have a 4-inch round bar of steel from which I wish to forge a cutter 7½ inches diameter, 1¼ inches thick. I want to cut a piece from the bar just long enough to make the forging, and I have a hammer heavy enough for the job. How shall I determine the length to cut off, and what is the percentage of loss?

A.—The percentage of loss will vary somewhat with different ways of working it. The loss from scaling or oxidation will be hardly perceptible in steel of that size, and the actual loss will be confined to whatever scrap may be made, which will be a very small amount if you are properly fitted up for the job. The cutter 7½ inches in diameter and 1¼ inches thick will contain 55.22 cubic inches of steel, and it will require 4.4 inches of the 4-inch bar to contain an equal amount. It is not, however, necessary to compute the solid contents, as the lengths can be found by squaring the diameters of the two bars; then the length of the smaller bar will be in the same proportion to the square of the diameter of the larger bar, that the length of the larger

bar is to the square of the diameter of the smaller bar. The proportion in this case would be:

16 : 1.25″ :: 56.25 : 4.39″.

In other words, the rule would be: Square the diameter of the bar and cutter, multiply the square of the diameter of the cutter by its thickness, and divide this product by the square of the diameter of the bar. The result will be the required length to cut from the bar, exclusive of waste. The waste will vary according to circumstances, but should not exceed 5 per cent.

744. Q.—Which is the best acid or liquid to use for soldering cast iron?

A.—The process is very much the same as soldering on a tinned surface. If the part of iron to be soldered is cast iron that is hard or thin, it should be polished on an emery wheel and made clean and bright; then dip it in potash water, after which dip it for an instant in clear water, and wash it quickly with undiluted muriatic acid of ordinary strength; go over with powdered rosin and solder made from half tin and half lead. This must be done quickly, before the surface has time to dry. Another plan is this: File the surface clean and wash as before; wipe it over with a flux made of sheet zinc dissolved in muriatic acid until it is a saturated solution, then sprinkle powdered sal-ammoniac on it, and heat it on a charcoal fire until the sal-ammoniac smokes; dip it into melted tin, and then remove and rap off the surplus tin.

745. Q.—Is it necessary—and if so, why—to cut off from ⅛ inch to ⅜ inch of the point of a rock drill at every third sharpening? The rock is very hard and the drills come back to the blacksmith often with the corners worn off.

A.—It is only "necessary" because it is expedient to do so. Drills used in hard rock have about as severe duty as steel ever encounters. No steel can be heated and worked and tempered over and over again by even the most careful blacksmith without deterioration, and the cutting off of the small amount suggested is no more than would be proper to keep the cutting end in good condition.

746. Q.—Does a fine texture grain in steel (after hardening) always indicate a good cutting material?

A.—No, not exactly. It simply indicates usually that the steel has been hardened at the proper temperature to put it in its

best condition. With some brands of steel and for some purposes this may be just right without tempering; but usually the temper must be drawn, and, supposing the forging and hardening to have been done properly, the quality of the cutting edge will depend upon the skill used in drawing.

747. Q.—I buy iron or steel, weigh it carefully, take it to a blacksmith, have it cut up and forged to shape, without apparent waste; I weigh the forgings carefully when done, and always find that they fall considerably short of the first weight of the metal. How does this occur, and what is the percentage of loss in forging iron and steel? Does a piece of iron or steel brought to a red heat and allowed to cool without hammering lose a certain part of its weight? Will a milling cutter or other similar article change its weight in hardening?

A.—Mr. B. F. Spalding answers as follows: "If there is no waste in scrap there is no reason for any diminution in weight, execept through oxidation. The loss from this source may be determined by the amount of scale produced. The scale, scrap and finished product collected should weigh as much more than the original metal as the weight of the oxygen which has entered into combination with it. This amount will vary in proportion to the amount of exposure it has to the action of the air while rendered susceptible to its effects by heat. The loss of metal by scaling is greater on small than on large work, more on squares and flats than on rounds and octagons. It should not exceed 2 per cent. per heat on one inch square steel, or 15 per cent. on half-inch round iron. The specific gravity of steel diminishes by hardening in proportion as the metal increases in volume. This amount is governed by the conditions to which it is subjected, and no rule of percetnage is of universal application. The absolute weight of the whole piece may or may not change, as it is subject to these conditions. Practically, the difference in weight should not be observed.

748. Q.—How may gun barrels be blued?

A.—Apply nitric acid, and allow it to eat into the iron a little; then clean, oil and burnish. The blue color on wrought iron and steel is also produced by various other processes; it is, in some cases, due to a certain amount of oxidation corresponding to a definite amount of heat.

749. Q.—What is the most practical method of bluing steel, and what degree of heat should a gas oven be kept at while bluing?

A.—The "temper colors" are as follows: 425 degrees Fahr., pale yellow; 450 degrees, straw; 475 degrees, orange; 500 degrees, brown; 550 degrees, purple; 555 degrees, violet; 580 dedegrees, blue. To blue steel proceed as follows: First, coat lightly with linseed oil; then sift dry hardwood ashes over the pieces with a sieve until they are covered; place them in a furnace, and heat until the color begins to change to a blue; after which they are cooled in the air, the ashes brushed off, and they are placed in a wire basket and immersed in sperm oil; when taken out they are washed in a solution of soda to remove all oil. The linseed oil causes the ashes to stick. The process is called ash bluing. Articles to be blued must, of course, be polished and clean.

750. Q.—Please give me the formula used by the United States Government for bluing guns. I have some fine steel plates on which I want to get an even dark-blue surface.

A.—An excellent method of bluing has been introduced into the National Armory at Springfield within a few years by Colonel Buffington, the commandant. It has proved so satisfactory in every respect that it has since been introduced into a number of private manufactories. The apparatus required for bluing by this method consists of a rectangular cast-iron tank of suitable dimensions. This is made rounding at all corners to diminish the liability of its cracking by expansion or contraction. It is permanently set over a furnace. The tanks in use at the armory are of sufficient size to hold a mixture of 20 pounds of black oxide of manganese, with 180 pounds of potassium (200 pounds of the mixture in the proportion of 1 to 9). When a fire is built in the furnace, underneath the tank, the saltpeter melts, and the manganese settles to the bottom in a thick, muddy sediment. When the workman is ready to commence operations, he stirs up the manganese and then ascertains whether the bath is of the right temperature by throwing upon it a sprinkling of dry sawdust. If the conditions are right the sawdust will instantly sparkle and ignite, but if the bath is not quite hot enough the sawdust will glow for some time before taking fire. If the bath is of the proper temperature, the

work—which must be assuredly dry—is immersed in it and allowed to remain there until it is heated to the same temperature. If it is tempered work, it is plunged for a few seconds into cold water to set the temperature as soon as it is taken from the heating bath. In case the work is not tempered, this plunge is omitted. It is then dipped into boiling hot water for a moment and then immersed in a tank of oil. When it is cool it is removed from the oil, allowed to drain, and subsequently wiped off; it is found to be of beautiful dark blue, of greater depth and permanence than that obtained by other processes. Either iron or steel is thus blued. Great caution is exercised to prevent the niter from coming into contact with the fire, on account of its expansive and explosive nature. The tanks are removed as soon as any sign of cracking appears and others are substituted in their place. In order to produce the best results it is necessary that the surface shall be made thoroughly clean. If a piece of highly polished steel is simply touched with the uncovered hand, there will be an impression left upon it, which will show after it is blued, unless the imperceptible stain is removed before heat is applied.

751. Q.—Can steel be case hardened, and if so, how?

A.—Case hardening is a process of converting the surface of iron to steel, and then hardening it. Applied to steel proper the term is a misnomer. So-called steel that will not harden by the ordinary process of heating and cooling may be treated like wrought iron for getting a hard surface. If it is desirable to get a hard surface on steel, leaving the center comparatively soft, heat the outside quickly in a lead bath and cool in water.

752. Q.—Please give me a receipt for a liquid solution for case-hardening machine steel and wrought iron?

A.—Melt cyanide of potassium in a crucible, thereby obtaining a bath, in which heat the articles until they are red hot; then take them out and cool in water or oil. Some recommend equal parts of cyanide of potassium and common salt fused together. By way of caution it may be said that this process of hardening will pit some kinds of steel, but this does not occur in iron.

753. Q.—What will case harden machinery steel, say about 1-64 or 1-32 inch deep? I have tried carbonate of potassium and

cyanide, but neither will act right. Also, is there anything I can use to harden set screws in small quantities?

A.—If you want to harden the steel to the depth mentioned you must put it through the regular case-hardening operation—*i. e.*, pack it in bone charcoal and heat it. Set-screws, to be hardened properly, must be done in the same way, as a mere hardening of the thin outer surface does little if any good.

754. Q.—We have a few malleable iron castings that we wish to harden and would like to have them all the way through. Can you give us a receipt?

A.—We are not sure that you can harden these castings all the way through; that will depend somewhat upon their thickness. They can be hardened to a considerable depth, however, by heating, preferably in a lead bath to a cherry red, immersing in cyanide, again heating and then quenching in cold water. A preferable method, however, is to heat them in a bath of red-hot cyanide and then quench in water. This makes the castings very hard.

755. Q.—Is there any way of hardening cold-rolled shafts besides the potash method, as potash only hardens for a depth of 1-16 inch at each process? The shafts are 4 inches diameter and turned to a point.

A.—Cold-rolled shafting can be case hardened by the ordinary method of case hardening with bone charcoal, but it is doubtful if the shafts can be in this way hardened deeper than 1-16 inch.

756. Q.—I wish to harden the heads of hexagon cap-screws in a case-hardening furnace. What is a convenient way of doing so without hardening the body of the screw?

A.—You can cover the body of the screw with a tube larger than the body, and fill in around the body with fire clay. This will prevent the body from hardening. A better way is to harden the entire screw, then heat so as to draw the temper or anneal. This will leave the outside surface in the condition of soft steel. You can then heat and harden the head precisely as if it were a steel screw.

757. Q.—How can I make and use a liquid case-hardening mixture?

A.—Take an ordinary sand or plumbago crucible large enough to hold two or three times the quantity of work you intend

to harden. Fill the crucible half way up with equal parts of fine salt and cyanide of potassium; set it on the fire, and heat up slowly till fused. Now, having the pieces to be hardened ready, plunge them all in together, and for a thin skin of hardening five minutes will be long enough, but if you wish a hard and thick film keep them in for a longer time. Afterwards the whole contents of the crucible must be poured quickly into cold water, not less than 12 inches deep, as the articles should become nearly cool before reaching the bottom. If the pieces are finished before hardening, they will come out a beautiful grayish white and hard as glass. It has also been suggested that instead of emptying the contents of the crucible into the water, thereby losing the material of the bath, the pieces to be hardened be suspended in the bath in a basket made from wire netting, and when properly heated the basket, with its contents, can be lifted out and plunged into the water, thereby saving the material. The mixture is highly poisonous, and care should be taken not to inhale the vapors arising from it.

758. Q.—How can I case harden wrought or malleable iron in a tight box?

A.—Make an iron box and put the articles to be case hardened in together with bone dust, fasten the cover on and lute all cracks with fire clay. Then submit the whole to a red heat from 1 to 4 hours, according to the size of the articles and the depth you wish them to be hardened. Remove the box from the fire and turn the contents into clear cold water, without exposing to the air. The color of the articles will be variegated. Instead of bone dust you can use saltpeter and leather scraps in the proportion of 8 pounds of the latter to one of the former. Pack the articles to be hardened so that they will not come in contact with the sides of the box.

759. Q.—What material should be put in water for hardening tubing, the thickness being No. 24 wire gage. I have tried dipping in a solution of cyanide of potash and water; it will harden heavy tubing, but not the light kind.

A.—If the tubing is of soft steel you can case harden it by melting a mass of cyanide or prussiate of potash, making a red-hot bath of it, in which the tube is heated for any length of time, and when sufficiently heated it should be cooled either

in oil or water. Another way to use these materials is to heat the tube in an open fire and sprinkle it with or dip it in the material, which for this purpose should be in a powdered form. The tube may be cooled as soon as the potash melts, or it may be laid back in the fire to soak, and dipping and soaking repeated until all the benefit possible is derived from the process, after which it must be quickly cooled. The tubes may also be hardened by the regular case-hardening process—that is, place the tubes in an iron box and pack them with carbon-yielding material, which must be selected for its fitness. It is determined by the quickness of the process and depth of hardening required; charred leather, from 1 to 3 hours; fine and then coarser granulated bone, as the period increases, from 1 to 24 hours; and hardwood charcoal for longer periods, with mixtures of these for any gradations wanted. The whole is then heated in the usual way.

760. Q.—What are the best proportions of metals to use for hard soldering light steel pieces, leaving the surfaces smooth; in other words, a spelter that will melt at a low heat and do substantial work?

A.—For fine steel work, solders containing considerable silver are used: say, 13 parts copper, 5 parts zinc and 82 parts silver. Hard spelter is made of 67 parts of copper and 33 parts zinc; soft spelter, of even weight of copper and zinc; 53 parts copper to 48 parts zinc makes a good brazing solder.

761. Q.—I wish to secure a brazing material, something with which two pieces of steel may be brazed together, then polished and blued, representing one piece of steel. Can you tell me how it is made?

A.—Solder for brazing steel is made as follows: Take 19 parts, by weight, fine silver, 1 part copper and 2 parts brass, and melt them under a coat of charcoal dust. This solder is comparatively white in appearance and renders the seams less observable, but we are inclined to believe that the joint will show to some extent after the steel is polished and blued; much will depend on the preparation and manipulation of the material during the process of brazing. Probably the best method for your purpose is to join the pieces of steel by electricity.

762. Q.—What tools are used and what kind of solder for the brazing

of large band saws, such as used in the lumber districts of the South and West? Will it do any damage to the saw to draw the temper?

A.—There are several methods of brazing band saws, among which is the use of brazing tongs and the blow-pipe. In either case the saw must be scarfed and held securely in place, while being brazed, by means of a suitable clamp. A piece of solder or soft, yellow brass must be placed in the joint, which must be liberally dusted with powdered borax. Heat may be applied either with a pair of heavy-jawed red-hot tongs or by means of a blow-pipe or alcohol lamp and a piece of charcoal held under the saw. Apply heat until the brass or solder melts, then press the saw ends together with another pair of tongs, which should not be stone cold, or the saw may be too hard at the joint. The temper is destroyed at the joint, but the space is so short that the working of the saw is not affected. After brazing, true up the joint with a file, sharpen the saw, if necessary, and it is ready for use.

763. Q.—In repairing broken parts of bicycle frames I cannot obtain good results in brazing. I use fine yellow spelter or common sheet brass, and borax for flux; it does not flow good; the tubing seems to scale before the spelter flows. Please let me know how to overcome the difficulty.

A.—Your trouble may be caused by not using the right kind of borax. There are three kinds of borax—the plain borax, borax which has been dried or calcined, and borax which has been melted and then broken to a coarse powder. The first kind when heated will swell, and does not flow readily over the surface. The second kind is nearly free from this defect. The third kind has nearly all the water driven out of it, and therefore forms a perfect covering for the metal. The common practice is to use some of the calcined borax and some of the melted borax, with which the joint is covered. The principal ingredients of the brazing solder should be copper and zinc; the proportion of the latter will govern the hardness; 2 of copper and 1 of zinc is often used for brazing; 1 of copper and 1 of zinc is more fusible. This solder can be bought of any composition. The work should be done quickly, because when the steel is exposed for a long time to a comparatively low

heat its quality will be impaired. On the other hand, the joint must not be placed in an intensely hot flame, as this also may injure the steel. Skill and experience are required for satisfactory results.

764. Q.—Is there any substance known that will prevent brass from adhering to steel when both are heated, as in brazing? I want to get a good, clean joint.

A.—Lampblack will effectually prevent the metals from adhering. The surface may be blackened by the flame of a lamp or candle, and care should be taken to avoid rubbing it off.

765. Q.—What is the best flux for brazing steel to iron, or iron to iron?

A.—When the alloy is made of copper and zinc, borax is used for the flux.

766. Q.—What will remove the borax from brazed work?

A.—The borax is best removed by means of a sand blast.

767. Q.—Please describe the process for tempering common helical car springs. The size of steel is 1⅛ inches to 1¾ inches in diameter, outside diameter of springs from 4 to 6 inches, hight 8 to 10 inches.

A.—For springs made of steel of such a large cross-section, the following process has been adopted: Heat the spring evenly to a cherry red, and immerse it in a tank containing fish oil, and swing it slowly back and forth, then cool in a tank of water. The period of immersion depends on the cross-section of the steel, and is governed solely by the operator's judgment; the time of immersion in oil will be about 35 to 40 seconds for the springs referred to; if on removal the oil on the spring takes fire, it should be re-dipped for a second and then put in the cold-water tank to cool off. To keep the tempering oil cool at an even temperature, the tank of fish oil is placed in a second or outer tank containing water, a circulation in the latter is maintained by a pump, the water being kept cool by a constant overflow. Resin and pitch are sometimes added to the oil to increase its hardening capacity. When only a few springs are to be tempered, the spring is heated evenly to a cherry red and immersed in fish oil, until, according to the operator's judgment, it is sufficiently cooled and then held over a blacksmith's fire and the oil blazed off, when a blue flame appears, the spring is removed and allowed to cool in the open

air. If after this operation it is found that the spring is too hard, it is re-dipped in the oil and again blazed off.

768. Q.—I have had some trouble in hardening my taps and dies, and getting them to the right color. How is this usually done by the tool makers?

A.—We assume from the language of your question that you know what the right color of taps and dies is, but that you have difficulty in securing this color, and we can only say that this is and must be a matter of practice largely, and the best method to pursue will depend much upon circumstances. Some toolsmiths simply hold such work over a clear flame in the forge until it is sufficiently heated, others heat a suitably formed piece of iron which may be a plate in the case of a die, or a ring in the case of a tap. The die may be laid upon the hot plate and watched until the proper color appears. With the tap it is simply held with the tongs in a central position within the ring, the radiated heat in this case doing the work.

769. Q.—What effect will soap, either hard or soft, have on tools, such as taps, reamers or milling tools?

A.—Supposing that you mean during the hardening operation, soap seems to tend to keep the articles bright and clean during the heating. We do not know that it has any other effect.

770. Q.—I am hardening a lot of chisels, and after the temper is drawn I can rub off the color. Can you tell me what will fasten the color? How can I harden a steel blade 1-16 inch thick and 1x6 inches so that it will not spring. Can I, after I have hardened a knife ½x2x6 inches, straighten it while drawing the temper?

A.—Mr. Goodyear replies to these questions: "1. Color on tempered steel will not rub off easily, if, after hardening, the steel is made bright before drawing the temper; look at clock and watch springs. 2. Use good steel which will harden at a low heat, and do not exceed the proper heat. Have the strain all out of the steel before heating for hardening. 3. Yes."

771. Q.—What is the best way to temper round spring steel, as rake teeth, for instance?

A.—Practice differs in this respect. In one manufactory where rake teeth are made the following plan is adopted: The bars of spring steel are cut to the proper length and all the fit-

ting required is done. They are then heated in a reverberatory furnace (which must be large enough to heat the pieces uniformly) to a bright-red heat and bent to shape over a former. When cooled to a low red heat they are dropped flatwise into a bath of linseed oil and allowed to cool. They are then tempered in the same furnace (run quite low) by holding them in the furnace and heating until the temper is brought down. This last operation depends for its success entirely upon the skill of the operator. A good quality of steel must be used, and failures must be expected before the operator educates himself to secure uniform results.

772. Q.—How can I temper cast-steel mandrels so that they will not break in driving them in and out of work?

A.—If good steel is used and the temper left the same as for a hammer, they will not break. It is a good plan to heat mandrels in a lead bath; then, being thus heated quickly, they will have a soft core after hardening.

773. Q.—What is the process and what are all the things necessary for drawing temper in large quantities of bits or cutters? Which is the best way to anneal steel in bar lengths?

A.—Mr. B. F. Spalding replies as follows: "The best way to draw the temper on small articles, as bits and augers, is to immerse them in a fluid of the right temperature and allow them to remain until all have the same heat. A tank of oil regulated by a thermometer is good for any heat less than will blaze oil. Many combinations may be made with vegetable, animal and mineral oils and tallows with beeswax, rosin, salt, soda, etc., to suit any purpose. Even temperature in any fluid must be secured by agitation if not boiling. With skill, sand may be used instead of a fluid; skillful handling will let the air to them and bring out any colors that are wanted. Bits may be bunched and augers set in frames so that a number of them can be handled as one piece. To anneal steel in bar lengths, the best way is to have a well-constructed furnace or muffle of sufficient capacity to receive the bars and heat them slowly. Softness is secured by prolonging the time of cooling from a red heat to a first blue. It is not good practice to heat steel in a hot fire, neither to heat in a slow fire if it has access to air. Extemporized furnaces should be clayed air-tight, be under perfect

control and closely watched. Overheatings are practically irremediable. A good practical blacksmith can anneal bars of steel in a forge fire by setting up a table behind the forge on which the anneal is banked. The end of the bar is put into the fire, and as fast as a portion is heated it is shoved along into the anneal. When the whole bar is heated it may be transferred to any pit of hot lime, ashes or sand, or of fine dry charcoal or sawdust. Air should be excluded.

774. Q.—How can I temper "chicken gaffs"? I want a good spring temper, and they must not break.

A.—Although a sketch of the article accompanied the question, we thought it best to look it up in the Century Dictionary, and we find that the "gaff" referred to is a metal spur bound to the shanks of fighting cocks. We, of course, recognize the necessity of a trusty weapon in warfare, but have not had sufficient experience in this precise line to know the temper best suited to the purpose. Most blacksmiths know, or should know, the common method of spring tempering. The article should be carefully heated to a bright red and cooled in oil. When thoroughly cooled it is kept wet with the oil, and held in the fire and slowly heated until the oil blazes, the blazing of the oil indicating the heat to which the piece has been raised. When the heat of the piece is sufficient to blaze the oil, it is laid down and allowed to cool. Only animal oil should be used for this operation.

775. Q.—How can the lead bath used for heating steel pieces for tempering be used so as to prevent it from wasting away? I have to be continually skimming off on top in order to keep it clean.

A.—Cover the surface of the lead bath with charcoal.

776. Q.—How should I harden dies made of Jessop's steel cut from the bar, planed up and engraved on one side? They are to be used for stamping spoons, borders or medals made of sterling silver, under a drop press.

A.—The process of hardening dies of this kind is a hazardous one, and should be intrusted in the hands of experienced men only. No matter how minute the directions for hardening work of this character may be there is always a great liability of failure unless the process is conducted by a man who is thoroughly familiar with it. The lowest temperature at which

the steel will harden should first be ascertained. The die may then be heated in a clean charcoal fire or in a muffle, taking care not to heat it too hot, and cool the engraved surface in water. Sometimes as a precaution against cracking the surface is covered with prussiate of potash or with a paste made of oil and soap, and when neither paste nor potash is used a little salt is thrown into the water in which the die is hardened.

777. Q.—I have a cast-iron box about 1½ inches wide, 3 inches deep and 9 inches long. I wish to melt lead in it to draw the temper in wood-working knives. Now, will you give me some information regarding this process, also number of degrees required for each color?

A.—Lead is not usually employed for drawing temper, but for heating to harden, the temper being afterward drawn by other means, such as oil, or by holding over a fire. The degree of heat required for such cutters will be about 490 degrees if they are not to be filed, and 570 degrees if they are. Thermometers for measuring such temperatures can be obtained of the makers of scientific apparatus. Lead melts at about 620 degrees, so that when melted it would already be hotter than the temperature desired. By using oil, and covering it over to exclude the air, the desired temperature can be reached, but it will blaze up as soon as air comes in contact with it. The articles to be tempered can be put into a perforated iron vessel having a handle by which it can be carried. This can be submerged in the oil, which is in another iron vessel having a cover, through a hole in which the thermometer can be passed. This is placed over a fire, and the heat slowly raised to the desired point, when the cover is removed, the inner vessel lifted up, and its contents dumped into sawdust or water.

778. Q.—How is the lead of a hardening bath prevented from sticking to a tap or reamer?

A.—It can be helped by first immersing the article to be hardened in soft soap. Or before doing this it may be previously partially heated. Or you may use the following solution: Equal parts of wheat flour and common fine table salt mixed with with water to make a thin paste and thoroughly stirred up. Dip the articles in this, taking pains to keep it well stirred up, as the salt has a tendency to settle to the bottom.

779. Q.—What is the solution which is used on taps and reamers by some makers in tempering which gives them a grayish or case-hardened appearance?

A.—This may be done by using for a bath equal parts of cyanide of potash and common salt. This can be heated and used for heating the articles, and can also be heated by a thermometer for drawing the temper. Where the temper is drawn in the usual way, so that the temper color is present, this may be removed by dilute muriatic acid.

780. Q.—I use whale oil for hardening small tools. How can I overcome or get rid of the abominable odor?

A.—A hood can be fixed over the vessel containing the whale oil and connected to a flue, which will carry off most of it. It would be better, we believe, however, to use cotton-seed oil, which would answer the purpose equally well and has no offensive smell.

781. Q.—How may I temper steel springs in disk form, say 1½ inches diameter, ¾-inch hole in center, and 1-32 thick? Of course I can temper in the usual way, in oil or hot water, or both, but this is too slow for my purpose, as I want to make them by the thousand.

A.—You can heat them in a lead bath and quench them in water or oil. The temper can be drawn in a vessel containing oil covered to prevent ignition, into which a thermometer may be introduced. They should be put into a perforated pan or vessel and let down into the oil, then the oil should be covered and the heat raised to the desired point, or they may be put into a vessel containing fine sand and shaken over a fire until the proper temperature is reached.

782. Q.—What kind of glass should be used for a bath in which to heat small articles to be hardened. Will scrap glass do?

A.—Yes; scrap glass will answer, it should be common lead glass; other kinds, such as the Bohemian, melting at too high a temperature, probably, for hardening tools.

783. Q.—To harden small steel tools, such as drills, I dip them in molten lead to heat them; then quench in water. This leaves a small quantity of lead upon the tools, also a disagreeable black color which I desire to remove. I am not much troubled by the lead, as I use strictly pure metal melted in a crucible.

Also will drawing in a hot-air oven or an air-tight box filled with charcoal leave the drills brighter than drawing in sperm oil after the dark color has been removed?

A.—A dark color upon drills is not objectionable. What is wanted is durable drills that will do the work required of them more than appearances. If you will boil oatmeal so as to make a thin paste and dip the drills in it before heating them in the lead bath they will come out clean. We should advise you to draw the temper in oil rather than in dry air.

784. Q.—I am running milling saws for sawing cold steel rails, etc. What is the best plan known to temper them and keep them from buckling at the same time?

A.—We made inquiries at a saw works in regard to tempering this kind of saws, and were informed that saws for iron and steel are hardened in the same way that saws for wood are hardened, the only difference being in drawing the temper, which for wood saws is brought down to a blue, while steel saws are frequently left as they come out of the oil bath. Saws for wood are tempered in the following manner: The saw is first heated to a red, then plunged into a bath of oil, resin and beeswax, the proportions of which we could not learn. For drawing the temper they are placed between heated plates and then again dipped when the proper color is reached.

785. Q.—How may a staybolt tap be straightened after it is hardened?

A.—Scour it clean so that you can "watch the color run" upon it. Then bring it nearly or quite up to the heat to which it was brought in drawing the temper originally. While at this heat, straighten it, which can then be done without much trouble.

Drafting.

786. Q.—To become a good mechanical draftsman, is it necessary to have a knowledge of algebra, geometry, trigonometry?

A.—Yes, the services of a draftsman with a good education are certainly more valuable than those of one with an indifferent education.

787. Q.—Is a knowledge of electricity of any use to a mechanical draftsman?

A.—Yes; in fact when he has to construct electrical machines a knowledge of electricity is indispensable.

788. Q.—What kind of wages does a mechanical draftsman receive?

A.—That depends on his ability and energy; there are no regular rates of pay for draftsmen. Some receive as much as $4,000 a year; others very much less.

789. Q.—What would be the size of a brick made ¼ size, the standard brick being 2x4x8 inches?

A.—According to the general understanding and practice among mechanics, it would be ½x1x2 inches.

790. Q.—What would be the size of a drawing of the first dimensions given made ¼ size?

A.—½x1x2 inches.

791. Q.—What kind of varnish can I use on mechanical drawings? The same must be white, transparent, dry quickly and hard, and have a glaze. I have tried but cannot find anything to answer the purpose. There is a varnish used in locomotive shops, but it seems to be kept there.

A.—The varnish used in many locomotive and other shops is simply white shellac dissolved in alcohol. It requires a little experience to mix these to the proper consistency, but this you will soon acquire.

792. Q.—I am trying to learn mechanical drawing, but find some trouble in inking my drawings, but whether in the ink or in the pen I am unable to tell. When the pen is first dipped in the ink it will mark very heavy for an inch or so, then very light, then not at all. Can you tell me what is the trouble?

A.—We should suppose by your letter that you had dipped your pen in the ink, which would account for its not working properly. Put the ink between the blades with a small piece of wood whittled quite thin and flat. The trouble may be in your ink; this may be of poor quality, or you may not rub it down properly. It should be rubbed very slowly and carefully, otherwise you will have trouble of the kind you describe.

793. Q.—Can you tell me anything to put in India ink that will keep it from evaporating?

A.—No. Grind the cover on the dish so that it will be air-tight, and keep the ink covered.

794. Q.—Is it customary to use a different color of ink for dimensions and lettering on a drawing?

A.—No, it can hardly be said to be customary, although it is sometimes done. When red ink is used the corresponding lines on the blueprints are distinguishable only by being somewhat less bright than the others.

795. Q.—Can tracing paper be used with as good results as with tracing cloth for making blueprints?

A.—If only one print is to be made, and the tracing is to be laid carefully away, and not handled, the paper will answer, but for regular use it is not suitable.

796. Q.—Would you recommend a student of drawing to use a section liner? I should think that by not using it I would get better practice in doing neat work under difficulties.

A.—You are right; we prefer to have the students draw the section lines with the "T" and set square and not rest satisfied until they can produce as good work as can be done with a section liner. Of course, more time will be needed, but the time will be well spent.

797. Q.—I find it difficult to make the ink stick to tracing cloth. Will you please inform me of some way to overcome the difficulty?

A.—With a woolen cloth rub some powdered chalk over the surface on which the ink lines are to be drawn, then wipe the surface clean, and use a good quality of India ink.

798. Q.—How do draftsmen describe circles 1-16 to ¼ inch and small curves with a drawing pen without making ragged lines? My compasses will not do it.

A.—This is largely a matter of skill and practice, but it is

greatly facilitated, of course, by having proper instruments, and for striking small circles a small bow pen should be used. These you will find illustrated and described in the catalogs of makers of such instruments.

799. Q.—What is a good red ink to use on blueprints?

A.—Why not use a water-color paint, mixing it so that it will flow in the pen?

800. Q.—What is a satisfactory method of shading tracings upon the back side of the cloth, so as to produce good results in blueprinting?

A.—We know of nothing better than a soft lead pencil.

801. Q.—How can I fix lead-pencil marks or sketches so that they cannot be easily erased?

A.—Sponge them with milk carefully skimmed, then lay blotting paper over and iron with a hot flat iron.

802. Q.—What stamp, either rubber or metallic, will make a good impression upon the glazed side of tracing paper, such impression to come out fairly well in a blueprint?

A.—Tracing cloth or paper may be printed upon either side, from metal type much better than from rubber stamps. Use quick-drying, heavy-bodied printers' ink, such as a wood-cut or half-tone ink, with a little drier mixed with it, as the tracing cloth is non-absorbent and the ink dries slowly. This ink may be had in small tubes from Charles Hellmuth, 379 Pearl street, New York City. Apply the ink with a composition hand roller, which may be had at any printers' supply store. Squeeze a little ink on a glass plate and spread until the ink is evenly distributed on the roller, touch the type to the roller and print on the cloth by hand, one or two letters at a time, since the strength of the fingers is not sufficient to impress many characters at once. A small printing press will do the work more conveniently if much is to be done. After printing, powder the ink with whiting or chalk to absorb the oil and thus aid in drying, also to increase the density of the ink.

803. Q.—I have noticed references to the Chinese writing stick recommended for writing the dimensions on drawings. Can you enlighten my ignorance with regard to the article or refer me to a dealer who can supply it?

A.—The Chinese stick is made of hard boxwood; its out-

ward form is like that of an ordinary lead pencil, and about equal in diameter. One end is sharpened to a conical form like an ordinary lead pencil, and brought to a sharp point; on the conical part a small channel or groove is cut for holding the ink; the stick is then used like an ordinary pen and gives the same results as are obtained with a stylographic pen. The advantage claimed for the use of this stick is that all parts of figures or letters are of equal thickness, hence the liability of losing a part of a letter or figure in blueprinting is not so great as when figures or letters have been written with a pen, which are liable to have thin and heavy parts, of which the thin parts are frequently lost in blueprinting. You will have some difficulty in finding a dealer who can supply these sticks; you can, however, make one very easily.

804. Q.—What is the meaning of the term "cross-section" as applied in mechanics?

A.—This term means a section of something made by a plane passed through at right angles to one of its axes, especially to its longest axis. This term is not often applied to boiler plates, but when it is so applied we should take it to mean a section made by passing through it a plane perpendicular to its surfaces and extending across the width of the plate. The term is applied more frequently to the whole boiler, for instance, the cross-section of a boiler means the section made by a plane passed through it perpendicular to its length. In making a drawing of such a section, everything that this plane cuts, or is supposed to cut, must be clearly shown, and the surface due to the cut must be section lined. By term "plane" is meant a perfect flat surface—that is, something which has length and breadth, but no thickness.

805. Q.—I bought a book treating on mechanical drawing, which I believe is first class in every respect and easily understood. Is it possible to learn drawing from such books sufficiently to enable a person to enter a drawing room as a draftsman?

A.—Yes; of course you will not be an experienced draftsman. It requires years of experience in practical and theoretical matters to become competent to fill any position in the drawing room; in fact, those who strive to be at the head of their profession never get through learning.

806. Q.—I am a draftsman and am sometimes asked by a man who runs a planer to what angle some piece is to be planed, which I give him from the horizontal plane. He claims this is wrong, and refers me to his planer head to prove his assertion. The question I want to ask is, who is right?

A.—For all we can see, you are both right. It is proper to measure an angle from a vertical, a horizontal or an inclined plane, and it is also proper to indicate on the drawing from what plane it is measured. At the same time if any number of degrees were spoken of without further reference, we should understand it to refer to the horizontal plane.

807. Q.—I have bought a set of Swiss drawing instruments. Since then I have seen several other sets by different makers, which seem just as good as mine, but I had to pay twice as much. What causes the difference?

A.—If you have bought the instruments of a first-class dealer, you have undoubtedly better instruments than the cheaper sets you have seen. There is no conspicuous difference in the outward appearance in the good and the poorer grades of instruments; to the latter can be given an appearance equal to that of the best grade, and with their joints carefully lubricated they are liable to deceive experts, and certainly will deceive those who have no experience in the use of them.

808. Q.—What can I use to cement tracing linen to a board securely without discoloring the tracing?

A.—First varnish the face of the tracing with a solution of white shellac and alcohol, and then hang up to dry; when dry, spread over the back of the tracing a solution of gum arabic and water or ordinary mucilage, and paste the tracing to the board. The idea of varnishing the tracing before it is pasted to the board is to prevent the lines from blotting when the tracing becomes damp by putting on the mucilage. Separate brushes should be used for the varnish and the mucilage, and another brush kept perfectly dry for spreading the tracing over the board. Each of these brushes should be thin and about three or four inches wide. Some practice will be necessary to paste the tracings evenly on the board.

809. Q.—In order to become a draftsman, is it necessary for one who has an inventive mind to be a mechanic or a pattern maker?

A.—A good draftsman requires some practical experience in the machine and pattern shop, and he should also know something of molding and blacksmithing. It is not always the duty of a draftsman to invent something new, but frequently he has to work out or design the details of machinery so that they can be made with the least expense, and with the tools available in the shop. This requires practical experience, and the more he has of this, in addition to a sound technical education, the better he will succeed.

810. Q.—Two positions as assistant draftsman have been offered to me. I am a machinist and receive from $15.00 to $16.00 per week. I have taken a full course at the Franklin Institute, and understand algebra and geometry fairly well and have had experience in drafting. My parents do not like me to leave home, and they believe that I cannot do better at drafting than as a machinist. What is your opinion?

A.—Good draftsmen receive more than $15.00 to $16.00 per week, and first-class machinists also receive more. In our opinion, good machinists, with a technical education, energy and pluck, have as many opportunities, if not more, to obtain high-salaried positions as first-class draftsmen who have but little shop experience. If your shop experience in the different departments is limited, we should advise you to continue to work in the shop. If, on the other hand, you have worked in the different shops, or at various classes of work, and have become familiar with the general routine of doing work it will be advantageous to enter the drawing room. Of course, the wishes of your parents should also influence your actions.

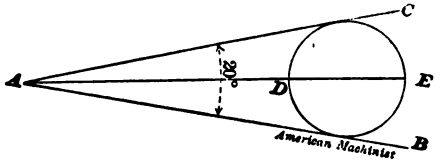
811. Q.—How are finished surfaces indicated on a drawing or blueprint?

A.—The best way to indicate on the drawing the surfaces which are to be finished is to write on the lines which represent the finished surfaces "finished," "tool finish," or "faced," according to the degree of finish required. The single letter *f* is frequently used.

812. Q.—How would you get the correct diagram of a circle inclosing a stated number of balls, as in a ball case for a bicycle?

A.—We would be quite likely to do it graphically, as here shown. The number of balls would determine the angle or the

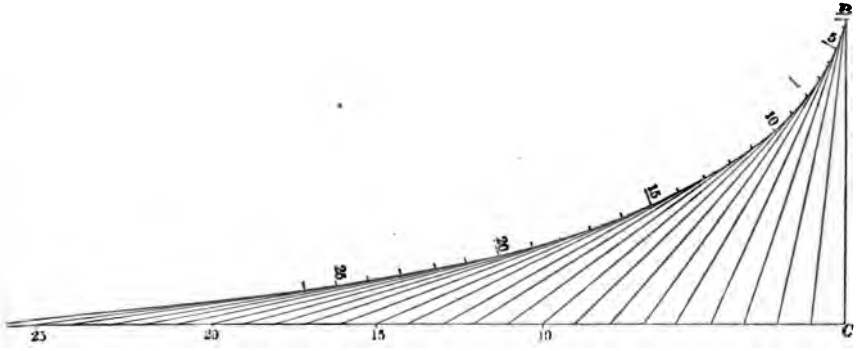
portion of the circle occupied by each. Say that the number of balls is 18; then each ball will require 20 degrees. Draw a



circle representing one of the balls; and if the balls are small, it may be drawn much larger than the actual size. Draw the two lines *A B* and *A C*, each tangent to the circle and forming at *A* an angle of 20 degrees. Bisect the angle by the line *A D E*. Then *A E* will be the radius of the required inclosing circle, and *A D* will be the radius of a circle which the balls will inclose —both, of course, upon the same scale as the first circle.

813. Q.—Will you please describe the meaning of "anti-friction curve" as applied to lathe bearings and the way of laying it out?

A.—You probably refer to the curve called the tractrix, also sometimes called Schiele's anti-friction curve, from the fact that he invented an instrument for drawing it mechanically.



The cut illustrates a method of drawing this curve. In this example, divide the line *C D* into any number of equal parts, and at *C* erect the perpendicular *C B* (length assumed at pleasure). From the several points of divisions on the line *C D*, draw

lines to the point *B*. The problem now is to draw a curve from *B* that shall cut these lines in such a way that they shall all be of the same length and equal to *C B*. This may be done by laying off on each of these lines a distance equal to *C B*, and drawing a curve through their extremities.

814. Q.—I am interested in perspective drawing and have picked up some ideas, and can make a good straight-line perspective, but as most of my drawing is of machinery, I meet with some obstructions that I am not able to surmount intelligently. In making a perspective view of a pulley or gear by the straight-

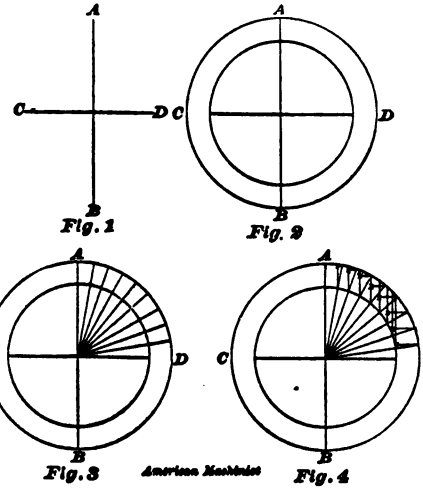


Fig. 1 Fig. 2

Fig. 3 Fig. 4

line rule, I can get the perspective width and depth of a square representing the side of a pulley, but I have no rule for describing the ellipse on a scale small enough for my use. Can you help me?

A.—To describe an ellipse is really a simple and easy operation. The sketches show how to get the points for one-quarter of the ellipse, and the rest is, of course, done in the same way. Say that *A B* and *C D* are, respectively, the long and the short diameters. With the point of intersection for a center, describe the two circles, Fig. 2, corresponding to those diameters. Draw

at random any number of radial lines, Fig. 3, paying no attention to the equal spacing of them. From each point where one of the radii cuts the smaller circle, draw a perpendicular until it strikes the larger circle. From the points where the radii strike the larger circle, draw horizontal lines, each meeting its corresponding vertical lines. These points of meeting will be the points of the required ellipse. The points for the remainder of the ellipse may be determined in the same way.

815. Q.—Should a perspective view of a ball be round or not?

A.—That depends on the relative positions of the sphere, picture plane, and point of sight. The rays of light coming from different points of an object to the eye are called the visual rays. The points in which the visual rays pierce the picture plane determines the perspective of the object. These visual rays drawn from a sphere to the point of sight form a visual cone, and the curve in which the picture plane intersects this cone will be the perspective of the sphere. The point of sight and the position of the sphere being given, the picture plane may be taken in such a position as to intersect the visual cone in any of the conic sections. If the picture plane is perpendicular to the line joining the point of sight and the center of the sphere, the perspective of the sphere will be a circle; when the picture plane is not perpendicular to the line joining the point of sight and the center of the sphere, the perspective will be an ellipse, or may even be a parabola, or a hyperbola. Since none of the last three curves seem to be the proper representation of a body perfectly round, it has been customary to represent the perspective of a sphere by a circle.

816. Q.—Is it customary in the profession, when a draftsman receives a set of drawings, a few of which are partially and the rest wholly finished, to erase the name of his predecessor from any of the sheets and substitute his own? Would he not thus steal credit for what he never did?

A.—This is a question which is not so easily answered as appears at first glance. If each of the draftsmen concerned is nothing more than a draftsman and is responsible only for the drawings, not for design, then only the name of the draftsman who made any given sheet should appear upon it. But if the second man is to be in any way responsible for design,

or for anything more than drawings, then it would appear that his proper course would be to sign sheets of drawings previously made as "approved" by him, but not to erase the name of his predecessor. We think it is not "customary" for draftsmen to pursue the course indicated by you, and there are very few, if any circumstances, under which such a procedure would be justifiable. Where, as is usually the case, the draftsman is to be held responsible for the finished machine or structure going together all right, it is of course necessary for him, in case some of the drawings have been completed, to go over them and thoroughly understand them. He should then sign them as "approved," or, if he finds it necessary to make changes, mark them "altered" by A—— B——.

Railroad and Locomotive.

817. Q.—What is meant by the degree of a curve as applied to railroads?

A.—The degree of a curve is determined by the angle subtended at its center by a chord of 100 feet.

818. Q.—Suppose you have two locomotives, one with drivers 5 feet diameter, the other with drivers 4½ feet diameter, and other dimensions of both engines being the same, which engine will do the best work in taking a freight train over the road?

A.—The engine with the small drivers will have the advantage in a heavy pull on a hill, but given an ordinary train that the large-wheel engine can handle, and it will do the work with less cost of fuel than the small-wheel engine, and the cost of repairs will be less.

819. Q.—Suppose an eccentric on a locomotive should slip when running, can it be set again without removing the steam chest; and if so, how?

A.—When an eccentric slips on the road, the easiest way to get it back to its place is by a measurement taken from the other eccentric's position. If, for instance, the forward eccentric slips, the engine is placed with the crank-pin on that side on the dead center. The reverse lever is then placed in the full back notch and a scratch made on the valve stem close to the gland. The lever is now put in full gear forward, and the slipped eccentric turned till the scratch on the valve stem appears in the same position it occupied when the lever was in the back notch. Care must be taken to see that the slipped eccentric is not set in the same position as the backward eccentric.

820. Q.—Is it the general shop practice of locomotive builders to bore cylinders and face up valve seats after the cylinders are fastened in position on engine frame?

A.—The general practice is to bore and plane the cylinders, fit and bolt them together, and drill all other holes in them, in fact, to finish the cylinders completely before they are placed in position. In some shops, the only holes which are left to be

drilled by hand, after the cylinders are placed in position, are the bolt holes through the flanges of the saddles for bolting the cylinders to the boiler; but even these holes are in some shops drilled by machine before the cylinders are placed in position.

821. Q.—What is meant by the leading side of a locomotive?

A.—The term "leading side of a locomotive" is generally applied to the right-hand side of the engine, because the crank on the right-hand side when the engine is going ahead leads or goes ahead of the crank on the left-hand side.

822. Q.—When the driving wheels of a locomotive are put on the axle with cranks at right angles, can the wheels be turned to either side, or is there a right and left-hand side?

A.—The wheels should always be put on the axle in a position in which the right-hand crank will lead or go ahead of the left-hand crank when the engine is running forward. With the wheels pressed on the axle in this position the axle and wheels may then be turned end for end under the engine without affecting the relation of the cranks—that is to say, the right-hand crank will always lead, no matter which wheel is placed under the right-hand or left-hand side of engine. If the wheels are pressed on the axle in a position in which the left-hand crank takes the lead when the engine is going ahead, no amount of turning the axle end for end under the engine will bring the cranks in the correct position. You can very easily convince yourself of this fact by taking two pieces of wire, and turning the ends of each at right angles to each other; in one wire turn the ends so that when the wire revolves in the direction of the hands of a watch the right-hand end of the wire will lead; turn the ends of the other wire so that the left-hand end of the wire will lead when revolved in the same direction, and note the difference. Cranks should be put on the axle to correspond with the position of the ends of the former wire.

823. Q.—A locomotive has expansive tires and telescopic spokes; could the centrifugal force of the tires lift the engine from the rails?

A.—No. The telescopic spokes would prevent the transmission of any force from the upper part of the rim to the wheel center, and the centrifugal force of the lower part of the rim would be resisted by the rail.

824. Q.—What is the composition used for metallic piston-rod packing?

A.—A leading Eastern railroad uses the following: Tin, 100 parts; copper, 9 parts; antimony, 6 parts. These are to be melted in separate crucibles, and when at the most fluid temperature the tin is to be poured into the other metals and the mixtures well stirred with a stick of green wood. Especially should an iron rod be avoided as a stirrer, as particles of iron will be taken up and produce hard spots in the metal. Lead should also be avoided in alloys for this purpose, as it will collect dust and act as a lap on the piston-rod. The use of separate crucibles is considered important by some. Others do not consider this necessary, but first melt the copper, then add the antimony in small pieces, and finally the tin. Still others melt the copper and antimony in one crucible and the tin in another, pouring the tin into the other metals when all are at their most fluid condition.

825. Q.—When does a car brake hold the most, when the wheel is sliding or when the pressure is just a little less than to bring about sliding?

A.—The brake is most effective in stopping the car when the friction is not quite sufficient to stop the revolution of the wheel.

826. Q.—I rode on a locomotive a short time ago, and when the train was running down grade without losing steam, the engineer always put the reverse lever in the forward notch. Now, I think by keeping the lever well back so that the valve would have short travel, there would be less friction. What do you think about it?

A.—Running a locomotive without steam with the lever pulled back is destructive of valve seats and injurious to cylinders. Take the case of an engine with cylinders of 24-inch stroke, cutting off 6 inches of the stroke. As the piston moves from the point of cut-off to the point of release, a partial vacuum is formed in the cylinder, and as soon as the valve opens the exhaust, the hot cinder-laden gases from the smoke-box rush in to fill up the vacuum in the cylinder. During the return stroke, compression begins about 8 inches from the end of the stroke, and as the compression is too great for the valve to hold down, the latter is jerked away off its seat and causes the valve clattering so well known when engines are run hooked up

after the steam is shut off. Some cylinder cocks are made so that they will open when a vacuum is in the cylinder, and so prevent the hot gas from being sucked in. Opening the cylinder cock is a partial remedy for the evil effects liable to result from running empty cylinders close notched, because they admit air to destroy the vacuum and permit the escape of the air when compression begins, and so prevent the valves from being jerked off the seat. Having to admit air to the cylinders by cocks or relief valves is objectionable, because the tendency is to cool the castings which should be kept hot.

827. Q.—Will an ordinary Mack injector feed as much water as a pump on a locomotive?

A.—An ordinary injector on one road differs from the ordinary injector on another road. An injector of the proper size for feeding a locomotive will throw as much water as an ordinary locomotive feed pump.

828. Q.—Why is the flange of one pair of drivers left off some large ten or twelve-wheeled engines?

A.—The flanges are left off to enable the engine to go around curves easily. An engine with a long wheel base could not go round even a moderate curve with flanges on all the wheels.

829. How long will it take a railway train to travel 100 miles, traveling 50 miles the first hour, and then reducing the speed for every hour to one-half the speed of the preceding one, until the 100 miles are completed?

A.—The time to travel the 100 miles is infinitely great. It will never quite get there. The distance run in 7 hours would be as follows:

1st	hour	50	miles.
2d	"	25	"
3d	"	12½	"
4th	"	6¼	"
5th	"	3⅛	"
6th	"	1 9-16	"
7th	"	25-32	"

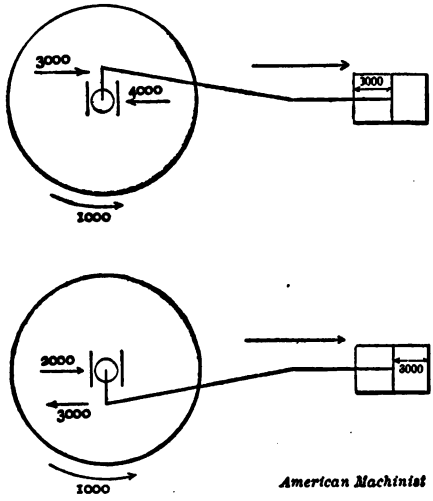
99 7-32 miles.

830. Q.—Will a locomotive pull the same number of cars backward as when in forward motion?

A.—As a general thing a locomotive will pull as much one way as the other. Where it will not do so, the difference is due to some arrangement of the valve motion, which gives opportunity to work more steam or to work steam more advantageously in one direction than in the other. Road engines usually have no provision for using sand when running backwards.

831. Q.—When a locomotive is working, are the alternate strains on the front and back pedestal jaws equal?

A.—They are not equal. When the engine is running ahead and drawing a load, neglecting here the angularity of the rod,



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the pressure or strain will be against the forward jaw when the crank is above the center, and with the crank vertical the strain will be equal to the *sum* of the piston pull and the pull on the track. When the crank is vertical below the center the strain will be against the rear jaw and will be equal to the *difference* between the piston thrust andthe pull on the track. Referring to the diagram this will be readily understood. The

drivers are assumed to be 6 feet in diameter and the length of the crank 1 foot. In the first figure, with the crank above the center, the pull of the piston being 3,000 pounds and the pull of the track 1,000 pounds, the resistance of the forward jaw to meet this must be 4,000 pounds. In the secon. figure, with the crank below the center, the resitance required at the rear jaw is only 2,000 pounds. This question of the pressure against the jaws is not to be confounded with that of the impelling force exerted upon the engine, which is the same for both strokes, except for the reduced effective area due to the piston rod. In the upper figure there is an excess of 1,000 pounds against the forward jaw, and in the lower figure there is an excess of 1,000 pounds against the front cylinder head, this excess of pressure in both cases acting to drive the engine ahead.

832. Q.—What I can I put on finished brass work for locomotives, which will turn it to glossy black? I do not want a paint:

A.—Give the articles a coat of japan varnish, and heat them in an oven in which the temperature is about 300 degrees Fahr., or higher. This will drive off the solvent of the gums or resins in the varnish, and the gummy residue becomes liquefied or semi-liquefied, in which state it adapts itself to all inequalities, and if the coating is thick enough, presents a uniform, glossy surface, which it retains on cooling. Varnishes are made for this purpose.

833. Q.—How do you calculate the pressure tending to force out the mud ring of a locomotive?

A.—Multiply the area of the surface of the ring which is exposed to the steam pressure by the pressure per square inch as indicated in the steam gage; the result will be the total pressure tending to force the ring outward.

834. Q.—Can excessive back pressure cause pounding in the driving boxes of a locomotive? Men frequently claim that increasing the size of the exhaust nozzle has stopped pounding.

A.—Excessive back pressure will tend to cause pounding in the driving boxes, and since the exhaust nozzle will affect the back pressure, there may be cases in which pounding has been stopped by increasing the size of the exhaust nozzle.

835. Q.—Can you give me a rule for the power required to start and

move a load on a level, as a railroad car, or a solid mass lying on a level surface.

A.—In many cases where a "rule" is asked for, it is not a rule that is wanted, but a book or library. Consult some standard treatise on mechanics.

836. Q.—What is the best course to pursue to become a competent locomotive engineer?

A.—Send your application to the superintendent of motive power, or apply personally to the foreman of the roundhouse He will probably direct you to whom you should apply. After you have obtained a position do your duty manfully, and do not neglect to study during your leisure hours.

837. Q.—What is the best method of brazing copper thimbles on iron tubes as practiced on locomotive work?

A.—J. G. A. Meyer replies as follows: "The usual practice in locomotive shops is not to braze the copper thimbles to the iron flues; they are simply laid on loose; then, allowing both the flue and thimble to project ¼ inch beyond the flue sheet both are expanded and rolled over. When we receive orders for locomotives in which the thimbles are to be brazed on the flues (which rarely happens) we order the thimbles to be brazed on the flues in the works in which the latter are made The method we adopt for the small amount of brazing copper thimbles to iron flues or pipes we have to do is as follows: The end of the pipe to which the thimble is to be brazed is thoroughly cleaned by filing or dipping in acid; then the thimble is placed in the correct position on the flue and both are heated over a fire; when hot, spelter is allowed to run between the flue and the thimble."

838. Q.—Can the horse-power of a locomotive be computed?

A.—Yes. It is found by the ordinary rule

$$\text{Indicated horse-power} = \frac{P \times L \times A \times N}{33{,}000}$$

in which P denotes the mean effective pressure for square inch of piston; L length of stroke; A area of piston in square inches; N the number of strokes per minute. This will be the horse power for one cylinder, which must be multiplied by 2 for the total horse-power.

839. Q.—Two locomotives are coupled together, each pulls 2,500 pounds,

the engines pull in opposite directions; what force is exerted on the coupling?

A.—Under the above condition the pull or the force acting on the coupling bar will be 2,500 pounds. Assume that one of the engines is coupled to a train of cars too heavy for the engine to move it, and suppose the engine is exerting a pull of 2,500 pounds. If the coupling bar breaks, the fracture is due to the force of 2,500 pounds acting upon it, and no more. The engine is pulling against a resistance, and it makes no difference in the force acting along the coupling bar, whether the resistance is caused by a train of cars or by another engine pulling in an opposite direction. Take an analogous case: Suppose a spring balance is attached to a 50-pound weight and the weight is lifted by the spring balance, then the latter will indicate 50 pounds, no more or less. Here we have the force of gravity acting at one end of the balance with a force of 50 pounds, and a force of 50 pounds exerted by the person who lifts the weight at the other end of the balance, and yet the force acting on the spring, as it plainly indicates, is 50 pounds.

840. Q.—What causes a locomotive whistle to squeal, and how can it be remedied?

A.—Water blowing through with the steam will make the whistle squeal; so will a big wind that blows part of the steam aside so that it does not strike the cap straight. The cap set badly will also cause squealing.

841. Q.—Does moving the cap nearer to or further from the steam opening affect the tone of the whistle?

A.—No; it affects the volume, but not the tone.

842. Q.—What causes a locomotive boiler to roar or make a kind of buzzing sound at times? Has the atmosphere anything to do with it?

A.—The atmosphere has nothing to do with it. This buzzing sound is caused by the circulation of the water in the boiler, and only occurs when the pressure of steam is comparatively low; at higher pressures this sound will not be heard.

843. Q.—For what reasons are railway axles made thinner in the middle than at the wheel fits?

A.—The reason for reducing the axle in the center is to reduce the rigidity of the axle, otherwise the constant jar will cause the axles to break at the wheel fit.

844. Q.—Railroad engineers say that the minimum curvature on a certain road is 30 degrees, and mention no radius. In the same way builders of locomotives say that an engine will run well on a 30-degree curve. Is there a standard radius understood, or what do they mean?

A.—Civil engineers designate curves by degrees—a one-degree (1°) curve has a radius of 5,730 feet; a two-degree curve has approximately a radius of one-half as much; a three degree curve one-third, and other degrees a proportionate fraction of 5,730 feet. Hence, to find the radius of a curve given in degrees, divide 5,730 by the number of degrees given, thus: the radius of a 30-degree curve is $\frac{5,730}{30} = 191$ feet.

845. Q.—If I tie a rope to a crank-pin of a locomotive wheel, the pin being on the bottom center, and pull at the end of the rope, in which direction will the wheel turn?

A.—If you pull hard enough, the wheel will tend to move toward you, provided you stand on the ground.

846. Q.—In speaking of railroad curves, what is meant by a 10-degree curve?

A.—When an engineer lays off a railroad curve, he lays off from the first station a tangential angle, then at a distance of 100 feet from the first station he establishes a second station, and from this he lays off a deflection angle which is equal to twice the tangential angle. After this, stations are established at 100 feet from each preceding one, and a deflection angle laid off from each station. The amount of curvature depends on the deflection angle, and therefore railroad curves are designated by the number of degrees in this deflection angle.

847. Q.—How is the number of degrees in a railroad curve determined?

A.—For curves over 500 feet radius, we get results sufficiently accurate for practical purposes by dividing the constant 5,730 by the radius in feet; the quotient will be the number of degrees of the curve.

Mechanical Powers and Movements.

848. Q.—Does a horse which exerts a pull of 500 pounds through a space of 66 feet per minute lift 33,000 pounds one foot high per minute?

A.—The horse is doing work equivalent to raising 33,000 pounds one foot high per minute. This is simply a question relating to rate of work performed, and it is computed by multiplying the force exerted by the distance through which it acts in a unit of time. Here we have $500 \times 66 = 33{,}000$ pounds raised one foot high per minute; in steam engineering, this amount is called one horse-power.

849. Q.—What was the standard horse-power taken from?

A.—It was established by Watt, who estimated that a horse could lift a little less than 33,000 pounds one foot per minute, but to make sure that his engines would do as much work as the horses, adopted the above as the measure of one horse-power, and this standard has since been adopted by continual practice.

850. Q.—Can a good strong horse perform that much work?

A.—If a good horse works four or five hours a day only, we believe it can do an equivalent amount of work, but it is generally admitted that for a longer period this estimate is too great.

851. Q.—Given two gears of equal diameter, one stationary and the other revolving around the stationary gear, how many times will the revolving gear turn on its axis in making one revolution around the fixed gear?

A.—The revolving gear will make one turn around its axis during one revolution around the fixed gear.

852. Q.—S. asks how to find the weight necessary to hang on the string to support the cylinder shown in Fig. 1 in any angular position. The cylinder is supported at its lower end by trunnions.

A.—Proceed as shown in Fig. 2, in which $a\,b$ is the center

line of the body in the position desired, *c* being the point of attachment of the string and *c d* the direction of the string

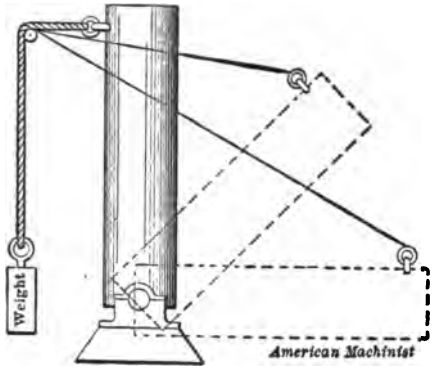


Fig. 1

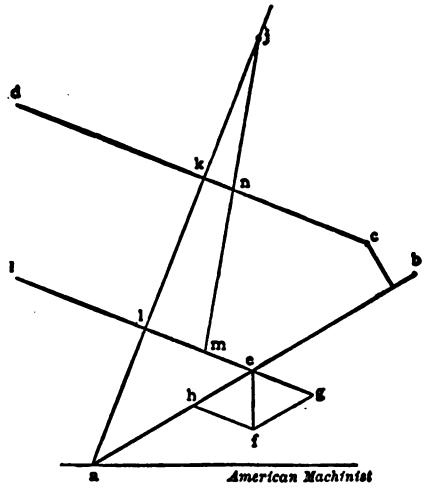


Fig. 2

for the position *a b* of the cylinder. Find the center of gravity *e* of the cylinder—in this case the center of length—draw *e f* to

scale to represent the weight of the cylinder, and at e construct the parallelogram of forces $e\,g\,f\,h$, $e\,g$ being the prolongation of $e\,i$, which is parallel to $c\,d$, and $f\,g$ being parallel to $a\,b$. The line $e\,g$ now represents the pull on the string if it were applied at e and had the direction $e\,i$. To find the pull on the actual string, draw $a\,j$ perpendicular to $c\,d$ and $e\,i$. Make $j\,k$ equal to $a\,l$ and $l\,m$ equal to $e\,g$. Draw $j\,m$, and $k\,n$ will be the pull required.

853. Q.—What is the centrifugal force in pounds of a 4-ounce weight revolving at the rate of 5,000 revolutions per minute in a circle, whose diameter is 4 inches? Please give rule.

A.—The centrifugal force is 348.34 pounds. The rule for computing the centrifugal force is as follows: Multiply the square of the linear velocity in feet per second by the weight of the body in pounds and divide the product by the radius of gyration, and by 32.2, the result will be the centrifugal force. For many practical problems, the distance from the center of rotation to the center of gravity of the body can be taken for the radius of gyration; in computing the centrifugal force we have taken 2 inches for the radius, and the velocity is that of a point coinciding with the center of gravity of the body.

854. Q.—What is the rule for finding the leverage of different screws and worms?

A.—In any simple machine the mechanical advantage is numerically equal to the quotient obtained by dividing the resistance by the power. By the word "power" in this case we simply mean the applied force, and the force to be overcome is the resistance. Let P denote the power, say in pounds; R the resistance in pounds; p the distance in feet through which the power moves, and r the distance through which the resistance moves; we have then

$$P \times p = R \times r, \text{ or } P : R :: r : p.$$

From which we get

$$\frac{R}{P} = \frac{p}{r} \qquad (1)$$

This formula shows that the mechanical advantage can also be computed by dividing the distance through which the power moves by the distance through which the resistance moves. These principles are also applicable for finding the mechanical

advantage of a screw. Suppose the nut to be fixed and the screw to be movable. In this case the power is applied to the end of a lever. Let l denote the length in feet of this lever, then the path through which the power moves during the revolution will be equal to the circumference of a circle whose radius is l, and this circumference in feet is equal to

$$2 \times 3.1416 \times l.$$

The distance through which the resistance moves is equal to the distance between the threads. Let us denote this distance in feet by d; now the distance $2 \times 3.1416 \times l$ will replace p in formula (1) and d will replace r; hence for the mechanical advantage of a screw we have

$$\frac{2 \times 3.1416 \times 1}{d}$$

Here, of course, friction is not taken into account.

855. Q.—How much of a load can a man lift with a screw 1⅜ inches diameter, 4 threads per inch, the screw is turned by the means of a hand wheel 26 inches in diameter?

A.—The circumference of the hand wheel is 81.68 inches, assuming that a man can exert a force of 50 pounds on the circumference of the wheel, then during one turn of the wheel an energy of $81.68 \times 50 = 4{,}084$ inch-pounds will be expended. Since the screw has 4 threads per inch, the distance through which the resistance will be overcome while the screw makes one turn will be ¼ inch; hence, if there is no friction, the pressure on the screw will be $4{,}084 \div ¼ = 12{,}336$ pounds. The friction will take up in this case about 60 per cent. of the energy exerted, leaving 40 per cent. only for useful work. Hence the pressure exerted by the screw will be $12{,}336 \times .40 = 4{,}934.4$ pounds.

856. Q.—I would like to know the dimensions for a Bessemer steel screw, screwed into cast iron, that will bear a weight of 28,000 pounds, allowing a factor of safety of 2.

A.—The elastic strength of Bessemer steel may be taken at 40,000 pounds per square inch. We want to sustain $28{,}000 \times 2 = 56{,}000$ pounds, and the sectional area of the screw at the bottom of the thread should therefore be 40,000 : 56,000 :: 1 : 1.4 square inch. Referring to the table of United States standard screw threads, we find the area of 1.515 for a screw 1⅝ inch

external diameter (5½ threads to the inch), and this size it would be proper to use under the conditions given. The factor of safety is quite low for any purpose, and we would prefer a 2-inch screw, 4½ threads to the inch. The safety factor would then be above 3.

857. Q.—There are five of these screws placed in a cast-iron head of a press; they are placed in a straight line at a distance of 4 inches between centers, distance between centers of supports, 20 inches; what should be cross-sectional area of the head which is tapped for the screws, also what should be the cross-sectional area of the same head when nuts 2¼ inches outside diameter are inserted for the screws?

A.—If the head is to be rectangular in form, without any nuts inserted, its depth should be 4 inches, and its width 5⅜ inches; with nuts, 4 inches deep and 6¼ inches wide.

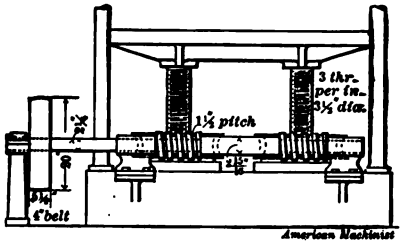
858. Q.—A weight of 1 pound falling 10 feet = 10 foot-pounds = 120 inch-pounds. This is said to equal a weight of 120 pounds falling 1 inch; or, to follow the same reasoning, 120,000 pounds falling 1-1,000th of an inch. A beam amply strong to resist the shock of 1 pound falling 120 inches would at once break under the heavier weight falling the shorter distance. Please point out the fault in reasoning.

A.—You confound energy with force. It is not energy which breaks the beam, but the force due to the destruction of the energy. If the beam is springy, the force due to stopping the small body may be much less than the simple weight of the large body, and a beam which would sustain the former would break under the latter.

859. Q.—Kindly give me the method of computing the capacity of a press as per enclosed sketch. The worm wheel has 38 teeth.

A.—We presume you wish to know what pressure this can exert. The worm-wheel having 38 teeth will make 1-38 of a revolution, while the 20-inch pulley makes one revolution. Since there are 3 threads per inch on the screw, the load will move through a distance of ⅓ of an inch for one revolution of the screw, or through $\frac{1}{3} \times \frac{1}{38} = \frac{1}{114}$ inch while the screw makes $\frac{1}{38}$ of a revolution. Hence, during the time that the pulley makes 1 revolution the load will travel through a distance of $\frac{1}{114}$ inch. The circumference of the 20-inch pulley to which the force is

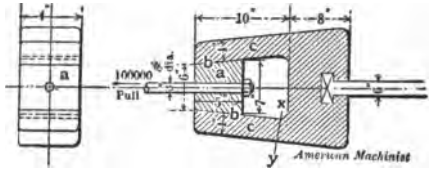
applied is 62.83 inches, and assuming that the belt can exert a force 45 pounds per inch of width, then the total force applied at the circumference of the pulley will be $45 \times 4 = 180$ pounds, and during one revolution of the pulley an energy of $180 \times 62.83 = 11{,}309.4$ inch-pounds will be exerted. Now the work done—that is, the distance through which the load is moved, multiplied by the load or pressure, must be equal to



11,309.4 inch-pounds. We have seen that the distance through which the load moves while the pulley makes one revolution is $\frac{1}{14}$ inch, hence the pressure exerted by the two screws will be $11{,}309.4 \div \frac{1}{14} = 1{,}289{,}271.6$ pounds, provided there is no friction. About 70 per cent. of the energy will be required to overcome friction, leaving 30 per cent. for the useful work done, hence the pressure exerted will be $1{,}289{,}271.6 \times .30 = 386{,}781$ pounds, or 193 tons.

860. Q.—What pressure will wedge *a* exert upon surface *b*, tending to break jaws off at *x y*, having a pull of 100,000 pounds on wedge *a* in the direction shown by arrows?

A.—There is a very simple method of solving all such



problems as the above if we only remember that, barring friction, the force with which any portion of a mechanism moves is inversely proportioned to its rate of movement. In the above case, if we assume that the wedge *a* is moved within the jaws

a distance equal to its length (5 inches), it will have moved the jaws apart 1 inch; and as the movement of the jaws is one-fifth that of the wedge, the force with which they will be moved is five times the pull on *a*, or 500,000 pounds. Of course, the frictional resistance between the surfaces of *a* and the jaws will modify this; its amount will depend upon the materials used, and in some cases also upon the amount of surface to which the pressure is applied, though, of course, this latter does not affect the result until the pressure per unit of area becomes so great as to alter the co-efficient of friction.

Computations—Geometry.

862. Q.—What is the rule for figuring out the amount of coal in a bin?

A.—Multiply the breadth of the bottom by the length of the bottom in feet, and thus obtain the number of square feet, or the area of the bottom of the bin; multiply this area by the hight in feet, the product will be the number of cubic feet in the bin. Bituminous coal, broken and loose, will weigh 47 to 52 pounds per cubic foot; we believe 50 pounds per cubic foot to be a good average weight to use in this calculation. Hence, multiply the last product found, that is, the number of cubic feet in the bin, by 50; the product will be the weight in pounds of the coal in the bin.

863. Q.—What is a correct rule for computing the pressure per square inch required to burst a cylinder made of material whose tensile strength per square inch is known. To illustrate: What pressure per square inch will be required to burst a cast-iron cylinder 10 inches inside diameter, metal 1 inch thick, tensile strength 20,000 pounds per square inch?

A.—Let S denote the tensile strength per square inch of the metal; t the thickness in inches; r the inner radius of the cylinder; p the pressure per square inch. Now the force which tends to rupture one side of the cylinder is equal to the product of the radius into the pressure per square inch, or $r \times p$. The resistance to rupture is equal to the product of tensile strength per square inch into the thickness, or $S \times t$. Hence, just before rupture $p \times r = S \times t$. From which we get

$$p = \frac{S \times t}{r}$$

Substituting for the symbols their values, we have

$$p \frac{20{,}000 \times 1}{5} = 4{,}000 \text{ pounds.}$$

This formula is applicable when the thickness of the metal in comparison to the diameter is small.

864. Q.—What would be the end thrust on the footstock of a lathe with

a parallel shaft weighing 2,700 pounds, resting on the centers which are the standard 60-degree angle? Is this right, making no allowance for friction?

$$\frac{2{,}700 \times .5}{.866} = 1{,}558 \div 2 = 779$$

pounds on one center, taking the sine and cosine of 30 degrees as the hight and base of a triangle, as it bears on the top of the center only?

A.—The method brings the correct result, but it might be arrived at a little more directly by saying that the end thrust would be as the tangent of the angle of 30 degrees; then taking half the weight of the shaft, 1,350 pounds, and multiplying this by the tangent of 30 degrees, .5774, we get 779.49 pounds.

865. Q.—What is the best and quickest method to find the distance to set over the tailstock on a lathe for turning tapers on heavy connecting rods, etc.?

A.—On connecting rods the taper is usually not given as so much per foot as it is in other work, but simply the diameters of the rod at the smallest part and at the largest part are given in figures. If the cutting tool were to be set level with the centers, and if the smallest diameter and the largest diameter of the rod were at the extreme ends of the rod, then the tail center should be set over to just half the difference between the smaller and the larger diameters; but as the latter condition is not present, it is necessary to multiply half the difference between the smaller and the larger diameter by the ratio which the over-all length of the rod bears to the length of the tapered portion; which ratio is found, of course, by dividing the total length by the length of the tapered portion. For instance, suppose the rod is of the marine type, 6 feet long over all, and that its smaller diameter is 3 nches and largest diameter 6 inches, and that these two diameters are at points 4 feet 6 inches apart. Then the arithmetical solution will be as follows:

$$1.5'' \times \frac{72''}{54''} = 1.99''$$

= distance to set over. This will give the distance to set over if the tool cuts level with the center, but it disregards the distance to which the centers enter the work. This, however, will not produce an error that will usually be appreciable in work of

this kind. Where the taper is given at so much per foot, then half the difference in diameter in the work at any two points 1 foot apart multiplied by the length of the piece over all in feet will give the distance the tailstock center is to set over, or one-half the difference in diameter at points 1 inch apart may be taken and multiplied by over all length in inches. This, however, will not produce exact results, because the tool can seldom be set to turn precisely level with the center, and the centers enter the work a distance which is not usually accurately determinable.

866. Q.—What is the cheapest method of finding the outside diameter of a milling cutter when the teeth are cut spirally and when the pitch and number of teeth are given?

A.—The term pitch we understand to mean the shortest distance between two contiguous teeth, or what would be called the normal pitch of the teeth, and the diameter of a cutter for it is found by multiplying the number of teeth by the normal pitch, this product by the secant of the angle of the spiral, and dividing by 3.1416. This may be expressed in the shape of a formula, as follows:

$$\frac{n\,p \cdot sec.\ a}{3.1416}$$

The angle here meant is the angle between the spiral or helix and the center line of the cutter, and is the same as the angle subtended between a line drawn at right angles to the axis, and one on which the normal pitch is measured.

867. Q.—In using a 1¼-inch bolt to draw in a bushing, what pressure can be applied by the bolt as compared with a hydraulic press for the same purpose?

A.—The probable breaking strain for a 1¼-inch bolt we find in Kent to be 39,000 pounds. The bolt will do well if it puts one-half of this strain, or, say, 10 tons, upon the bushing.

868. Q.—Give formulas for calculating the centrifugal force and the rim tension due to centrifugal force in flywheels.

A.—For centrifugal force, use the formula:

$$F = .000341\ W\ R\ r^2.$$

For the strain on any cross-section, use the formula:

$$S = .00005427\ W\ R\ r^2,$$

in which

F = centrifugal force of entire rim,
W = weight of rim in pounds,
R = mean radius in feet,
r = revolutions per minute,
S = total strain on any cross-section.

869. Q.—Can you give me a rule for finding the size of blank for drawing shells from sheet metal?

A.—To find the proper diameter of a blank for a tube of any size, first weigh the tube and then take a piece of stock of the thickness of the bottom of the tube (which is not affected by the drawing-up process) and cut out a circle that you know to be too large, then keep trimming it down until the weight of the tube and of the flat blank is the same. It is a very good plan to make the drawing dies first and the blanking die last.

870. Q.—What is meant by moment of inertia?

A.—If a body whose mass is M moves with a velocity v the stored energy due to the motion is $\frac{Mv^2}{2}$. If, however, the body revolve upon an axis, as for instance, a grindstone, it is plain that no such simple formula will express the stored energy, for the reason that different parts of the stone have different velocities, and a factor must be introduced to provide for this f ·t, which factor will obviously vary with the shape of the revolving body—a square disk, a round disk or a cone each having a factor of its own. This factor is called the moment of inertia, and it is found by multiplying the weight of each particle of the body by the square of its radius, and adding together all the products. This process is only possible through the methods of the calculus, although approximate results can be obtained by simpler methods. The expression "moment of inertia" is an unfortunate one, as it conveys the impression that it is the moment of the inertia of the revolving body, whereas in point of fact it is only the factor of that moment due to the shape of the body. It has sometimes been proposed to call it the measure of the moment of inertia, and such a name would better describe what it really is, but the practice has not prevailed, and probably never will prevail. It so happens that in treating of the subject of the strength of

beams a mathematical expression is found which is identical with the above-described moment of inertia and consequently it is called by the same name. This expression is found running through all discussions of the strength of beams, although in point of fact there is no inertia and no real moment of inertia involved in any body to which static forces only are applied. The use of the term in that connection grows out of the coincidence in form of two formulas obtained in very different classes of work.

871. Q.—How many gallons of water will a tank hold which is 37 inches deep, 96 inches wide and 118 inches long?

A.—A gallon of water is 231 cubic inches, hence if you find the contents of the tank in cubic inches and divide by 231 you will have the contents in gallons. Thus, multiplying together 37, 96 and 118 gives 419,136 cubic inches, which, divided by 231, gives 1,814½ gallons, nearly.

872. Q.—In reading scientific papers I have frequently met with the expressions "unit of heat" and "unit of work." Now, I know that a unit is a measured quantity, such as a pound of butter, but I do not see how it is applied in the way mentioned.

A.—In the case of the butter, the unit is the pound, which is the unit of weight, or the measure of weight in common use. The unit of heat, or, as it is commonly called, the British thermal unit, is that quantity of heat which is required to raise the temperature of one pound of pure water 1 degree Fahrenheit at or near 39 degrees, the temperature of maximum density. The precise temperature is not of great importance, except where minute accuracy is required, but the weight of the water is a most important particular. Any definition of the unit of heat which does not specify the weight of the water heated of course defines nothing as to the quantity of heat employed. We may raise the temperature of a pound of water or of a thousand pounds of water 1 degree, but it takes a thousand times as much heat in the latter case. The time consumed in the operation of heating is not an element of the case, as the same quantity of heat will be required whether transmitted quickly or slowly. The quantity of heat represented by the British thermal unit, as defined above, is equivalent to the mechanical energy required to raise 1 pound 772 feet. A unit of work is

the foot-pound or the raising of 1 pound 1 foot. It is to be noted that in this definition no time is specified. When the time limit is included we have then a unit of power, or a measure of the rate at which work may be done, or of the ability to do the work. The common unit of power is the horse-power, which is defined as the ability to raise 33,000 pounds 1 foot high in a minute. The horse-power hour is a larger unit of work which it is often convenient to use, and it means, of course, the amount of work that may be done by one horse-power operating for one hour, or in foot-pounds it is 33,000 × 60 = 1,980,000 foot-pounds. If we have a statement of a certain number of horse-power hours of work done, that in itself gives no information of the horse-power employed. A 100 horse-power engine working for ten hours, a 10 horse-power engine working for 100 hours or a 1 horse-power engine working 1,000 hours would each do the same amount of work—1,000 horse-power hours. These things do not usually become clearly defined in one's mind without some study of them, but a clear comprehension of them is necessary if one is to do much with engines or with power.

873. Q.—What is a good lubricant for steel driving axles and crank pins when being pressed into steel wheel centers?

A.—There are several lubricants for this purpose; linseed oil is sometimes used, and sometimes white lead. Probably linseed oil is as good as anything. It lubricates sufficiently when the pressing is done, and afterward hardens.

874. Q.—What relation does the angle of a helix bear to a turn in in so many inches? If I have one given, how can I find the other?

A.—The angle of the helix is that of which the circumference of the work divided by the number of inches to one turn is the tangent. In other words, to find the angle of helix, divide the circumference of the work in inches by the number of inches to one turn, and then in a table of natural tangents find what angle this quotient is the tangent of. On the other hand, if you know the angle look in a table for its corresponding tangent, and divide the circumference of the work by it. The quotient will be the pitch or number of inches to one turn.

875. Q.—If I have a drill or cutter before me, how can I find out its angle, or the number of inches to one turn?

A.—If the drill or cutter is long enough you can measure the pitch by a rule, but if it is short apply a protractor to determine the angle, and from that find the pitch by the rule given in the previous question.

876. Q.—C. has a cable reel 10½ feet long, 8 feet diameter over the flanges, and weighing 60,000 pounds, and he desires the dimensions of a shaft to safely carry the reel.

A.—In most cases of this kind it is a question of size of bearing rather than strength of shaft. Each bearing must carry 30,000 pounds, and for the speed at which such bearings turn we should expect a pressure of 200 pounds per square inch of projected area to give satisfactory results. $\frac{30,000}{200} = 150$, which is the proper projected area of each bearing, and it may be made up of various proportions of length to diameter. If we adopt a length equal to about twice the diameter, a bearing 8½x17½ inches would have the right area, or, for even figures, it might be made 9x16 inches. The strain on such a shaft may be regarded with sufficient accuracy as a shearing strain. A 9-inch shaft would have 63½ inches cross-section and $\frac{30,000}{63\frac{1}{2}} = 473$ pounds of shearing stress to each square inch, which is, of course, a trifling strain for the material. You have not given and we have not considered the strain on the rope, which would, however, probably be small in comparison with the weight of the reel.

877. Q.—What is the formula for the weight of a cast-iron ball?

A.—The following is the simplest formula for the purpose that we know: $D^3 \times .1365$. The D, of course, stands for the diameter of the ball in inches. Say that we have a cast-iron ball 6 inches in diameter, what will be its weight? $6 \times 6 \times 6 \times .1365 = 29.484$ pounds.

878. Q.—In the case of an ordinary punch for punching metals, what relation does the power required to punch the various thicknesses hold to the thickness punched, all other things being the same, and, all things being equal, what relation does the power required hold to the size of the hole punched? Does it vary as the area or as the perimeter?

A.—The best formula we know of is as follows: $P = 80\ D\ T$,

in which P = pressure in tons, D = diameter of hole punched and T = thickness of the metal. It is not to be understood that this rule will give exact results, but it is probably nearly correct for average conditions. By this rule it would require about 43.75 tons to punch a 7/8-inch hole through a 5/8-inch plate, but experiments have shown that the actual force required to do this varies from 33 to 35 tons, though under different conditions the pressure might rise to that indicated by the formula. From this formula it will be apparent, of course, that the pressure does not vary as the area but as the perimeter, the perimeter being in direct proportion to the diameter of a round hole.

879. Q.—What is the slide rule formula for finding the weight of hexagon bar steel?

A.—The ruling dimension of bar stock is of course the distance between the parallel sides or the diameter of the inscribed circle. If

d = diameter of the inscribed circle,
a = area of the hexagon,

then

$$a = d^2 \times .866.$$

Since the weight of steel is .2833 pound per cubic inch, we obtain; Weight per inch of length

$$= d^2 \times .866 \times .2833,$$
$$= d^2 \times .245,$$

giving the slide rule formula:

Find weight per inch of length on A
against .245 on B.

Set I on C
to d on D.

The diameter is of course in inches and the result in pounds. The usual precautions regarding the decimal point are of course to be observed.

880. Q.—Can I calculate the length of a helix of 1 inch diameter and 3 inches pitch?

A.—Conceive one turn of the helix to be rolled out flat. It will then be the hypothenuse of a right-angle triangle of which

the circumference is the base and the pitch is the hight. From the property of right-angle triangles

$$\text{hypothenuse}^2 = \text{base}^2 + \text{hight}^2,$$

or

$$\begin{aligned}\text{hypothenuse}^2 &= 3.1316^2 + 3^2,\\ &= 9.8696 + 9,\\ &= 18.8696.\end{aligned}$$

Extracting the square root gives

$$\text{hypothenuse} = 4.344.$$

881. Q.—What are the calculations necessary to find the load which will bend sheet steel 3-16 inch thick, ⅝ inch wide and overhanging 2½ inches from the support.

A.—The breaking load of a cantilever beam loaded at the end is found by the formula

$$P = \frac{R\,b\,d^2}{6\,l}$$

in which

P = load in pounds;

b = breadth, d depth, l length, all in inches.

R = tensile strength in pounds per square inch.

Taking R as equal to 60,000 and substituting the values of b, d and l gives

$$P = \frac{60{,}000 \times \frac{5}{8} \times \frac{9}{256}}{6 \times 2\frac{1}{2}} =$$

88 pounds.

If your steel has a higher tensile strength than 60,000 pounds, use the proper value in place of 60,000.

882. Q.—Will you publish a simple rule for tapering in a lathe?

A.—If the tool were set level with the center, and no allowance were to be made for the distance which the lathe centers enter the end of the work, then the rule would be: Divide the difference between the diameters of the small and large ends by 2, and multiply this by the ratio which the total length of the shaft bears to the tapered portion. In the case which you mention it would be $(2.5—1.25) \div 2 \times 3 = 1.875$ or 1⅞ inches. The fact that the centers enter the work a certain distance prevents accurate results being obtained by calculation, however.

883. Q.—How can I find the area of an oblong hole—say, for instance, a manhole on a boiler?

A.—Draw the outline of the hole on paper; across this figure, and parallel to its short axis, draw a number of lines dividing the figure into equal parts; measure the mean hight of each part, add these measurements together, divide the sum by the number of parts, and multiply the quotient by the long diameter; the product will be the area. If all the measures are in inches, the area will be in square inches. This rule will only give approximate results; the greater number of parts into which the figure is divided, the more accurate will be the result.

884. Q.—What will be the safe speed for a cast-iron pulley, 102 inches diameter, 31 inches face, 8 arms? Please give rule for finding the speed, and settle a dispute.

A.—For finding the bursting speed the following rule may be used: Divide the ultimate tensile strength per square inch of cast iron by 0.1; find the square root of the quotient; the result will be the velocity of the center of the rim in feet per second. Or, in symbols, we have

$$\sqrt{\frac{s}{0.1}} = v,$$

in which s = ultimate tensile strength per square inch of cast iron, and v = velocity of the center of the rim in feet per second. If the metal in rim has not been decarbonized at all by remelting, the ultimate tensile strength per square inch should not be assumed to be greater than 10,000 pounds. Under these conditions the velocity of the rim to burst it will be

$$\sqrt{\frac{10{,}000}{0.1}} = 316 \text{ feet per second},$$

or $316 \times 60 = 18{,}960$ feet per minute. For safety in practice the velocity should not exceed one-third of the above. Of course it is here assumed that arms are correctly proportioned for the stress which they will have to resist.

885. Q.—I saw a rule in your paper for setting a compound rest to bore a taper ⅛ inch in 3¾ inches. The answer called for 2 degrees, and I bored out a hole by that rule and it came out all right. Now I want to bore a hole 2 inches in 3¼ inches. The rule called for 11 or 12 degrees; but I had to set the rest 15 degrees to do the job. Will you please explain?

A.—We do not know where our correspondent found the

rule referred to; and whether the rule was right or wrong our correspondent is evidently wrong in the use of it, for an angle of 2 degrees will not give a taper of ⅛ inch in 3¾ inches. For boring or turning tapers with accuracy, the graduations by degrees are not sufficiently minute to be of much service; but when such computations are undertaken, it is well to have them as correct as possible, and they may sometimes serve in checking or watching operations. To ascertain the angle to set over the rest, we would first divide the difference in the diameters of the ends by the length; this would give us the chord of the arc corresponding to the angle of the taper, and from a table of chords the angle would be readily ascertained, and one-half of this angle would be the angle required for the set-over of the rest. The first case cited by our correspondent (converting all the figures into decimals) will give us: .125 ÷ 3.75 = .0333, and in a table of chords we find .0332 for an angle of 1° 54′, and one-half of this, or 0° 57″, or a little less than 1°, would be the correct set-over. In the second case by the same operation we have: 2 ÷ 3.75 = .5333, and by the same table of chords this corresponds to an agle of 30° 56′, and one-half of this is 15° 28′, or nearly 15½°. It is evident from this that with no means provided for indicating minutes, the graduations of the compound rest are not of much account in setting for tapers, except as a means of approximating.

886. Q.—S. asks: 1. For an easy and correct method of ascertaining the circumference of an ellipse from its diameters. 2. For a similar method of finding the diameters when its area and the ratio of its diameters are known. 3. For a similar method of finding its diameters when its circumference and the ratio of its diameters are known.

A.—1 and 3. There are no simple accurate formulas known for these purposes. 2. If D and d are the diameters, the area is expressed by the formula $D \times d \times .7854$. If $D = rd$ this becomes: area $= rd^2 \times .7854$, and by transposition,

$$d = \sqrt{\frac{\text{area}}{r \times .7854}}$$

887. Q.—What will be the diameter of the steps of a pair of cone pulleys, three steps to each, the driver making 133 revolutions

per minute, and the driven to make 50, 150 and 300 revolutions per minute?

A.—We have no idea in this case whether the work is heavy or light, or what amount of power is to be transmitted. This would naturally make a difference in the sizes of the pulleys employed, smaller pulleys being selected for light service and larger pulleys for heavier loads. Taking the middle step first, and assuming 9 inches for the diameter of the driver, we have:

$$150 : 133\tfrac{1}{3} :: 9 : 8 \text{ dia. of driven pulley.}$$

We have taken the liberty of adding ⅓ of a revolution to the driver speed, thus simplifying our work and securing a whole number for the diameter of the driven pulley. The sum of the diameters of this pair of pulleys being $9 + 8 = 17$, the sum of the diameters of either of the other pairs of pulleys will be approximately the same. The ratios of the driver diameter to that of the driven must be inversely as the speed ratios. The ratio of the diameters of each of the pair of pulleys to the sum of those diameters must be inversely as the ratio of each of the speeds to the sum of those speeds. The speed of the driver being 133.333, as before, and the required speed for the driven pulley being 50, the sum will be $133.333 + 50 = 183.333$, and the two ratios will be $\frac{133.333}{183.333} = .7272$ and $\frac{50}{183.333} = .2727$. Multiplying the sum of the pulley diameter 17 by each of these results, we obtain the required diameters of the two pulleys of this pair:

$$17 \times .7272 = 12.363;$$
$$17 \times .2727 = 4.636;$$

or, in the language of the machine shop, the driver would be a little more than 4⅝ inches and the driven pulley would be a little less than 12⅜ inches. By the same process for the other pair of steps, for the driven speed of 300 revolutions, we have $133.333 + 300 = 433.333$ Then: $\frac{133.333}{433.333} = .30769$ and $\frac{300}{433.333} = .6923$. Multiplying each of these results by 17 we have $.6923 \times 17 = 11.77$ and $.30769 \times 17 = 5.23$; these diameters being, as before, in shop fashion, a little more than 11¾ inches and a little less than 5¼ inches respectively. These diameters being thus ascertained they may, if thought necessary, be laid down

graphically upon the drawing board, and slightly corrected to secure the proper belt tension; but this precaution will probably not be necessary.

888. Q.—What is the tensile strength of a piston rod 10 inches in diameter?

A.—Piston rods are made of various materials, and the tensile strength depends upon the material. As the area of the rod is 78.54 square inches, if the material, say wrought iron, has a tensile strength of 30,000 pounds per square inch, then the tensile strength of the rod will be $78.54 \times 30{,}000 = 235{,}620{,}000$ pounds; so, if the tensile strength of the material is 70,000 pounds, which is common enough in steel, the tensile strength of the rod is 549,780,000 pounds. In determining the size of a piston rod for a given service, of course, a large factor of safety is used, depending upon the length of stroke, piston speed and other particulars.

889. Q.—Kindly give me a rule for computing the thickness of metal in a tank 20 inches inside diameter, made of mild steel; it is to withstand a pressure of 1,000 pounds per square inch.

A.—For computing the thickness of metal in this tank, we may use the ordinary rule for computing the thickness of boiler plates. Multiply the pressure per square inch by the inner radius in inches of the tank, and divide the product by the safe working stress per square inch of metal; the result will be expressed in symbols as follows:

$$\frac{P \times R}{S} = T; \qquad (1)$$

in which P = pressure in pounds per square inch, R = inner radius of tank, S = safe working pressure in pounds per square inch of metal, and T = thickness of metal in inches. For mild steel, double-riveted butt joints, we may take for S a value of 9,100 pounds; hence we have:

$$\frac{1{,}000 \times 10}{9{,}100} = 1.1 \text{ inches},$$

very nearly, for the thickness of steel in the tank. For these high pressures some engineers prefer to use the following formula:

$$\frac{P \times R}{S - P} = T; \qquad (2)$$

in which the letters denote the same quantities as before. According to this formula, we have:

$$\frac{1{,}000 \times 10}{9{,}100 - 1{,}000} = 1.23 \text{ inches}$$

for the thickness of steel. It should be remembered that the thicknesses as found above are for the cylindrical shell only.

890. Q.—The head of a drop hammer weighs 400 pounds, and falls through a distance of 10 feet, and then strikes a piece of cold iron which is compressed 0.01 inch; what is the striking force of the hammer?

A.—The stored-up energy of the head in falling through a distance of 10 feet is $400 \times 10 = 4{,}000$ foot-pounds. This energy must be expended before the head can be brought to rest. Now, in bringing this head to rest, work is performed which is found by multiplying the distance through which the head travels in coming to rest by the average force exerted, and this product must be equal to the stored-up energy = 4,000 foot-pounds. The distance through which the head travels in coming to rest is 0.01 of an inch = 0.00083 of a foot; hence the average force of the blow will be $\frac{4{,}000}{0.00083} = 4{,}819{,}277$ pounds. This is the theoretical force without making any allowance for the friction which may occur between the head and its guides, and the force expended in compressing the foundation, and even the anvil itself. If this data is known and taken into account in making the above computation, the average force of the blow as found may be much reduced.

891. Q.—Give a method of computing the force which a spiral spring can exert; I mean a spring wound like a watch spring.

A.—The force which a spiral spring can exert can be computed by the following formula:

$$P = \frac{S}{6} \times \frac{b \times h^2}{R}$$

in which P = force in pounds exerted by the spring, S = stress in pounds per square inch in the steel (the value of S will depend on the quality and temper of the steel, 24,000 pounds will probably be a fair average), b = the width of blade in the spring, h = its thickness, and R the distance in inches from the center of the spring to the point of application of the force.

892. Q.—How may I compute the strength of a helical steel spring, the diameter of the wire being given?

A.—The greatest safe load can be computed by the following formula:

$$W = .3927 \frac{S \times d^2}{D - d} \qquad (1)$$

in which W = safe-working load in pounds, d = diameter of wire in inches, D = outside diameter of coil in inches, and S greatest tensile stress in pounds per square inch of material, say 60,000 pounds. Multiplying 60,000 by .3927 we have a constant of 23,562, which may be used in place of S in the above formula, hence the above reduces to

$$W = \frac{23{,}562 \times d^2}{D - d} \qquad (2)$$

The ultimate carrying capacity will be about twice the safe load. The load as found above is suitable for intermittent working, for springs in steam-engine governors, or safety valves.

893. Q.—How is the stress per square inch in the rim of a flywheel computed?

A.—The formula for the tensile strain on the cross-section of the rim of a flywheel is 0.00005427 W R r^2, W being the weight of the rim in pounds, R the main radius in feet, and r the revolutions per minute (for derivation of the formula, see Kent's Pocket Book).

894. Q.—Does it not vary with different materials, other conditions remaining the same?

A.—It does. For cast iron the strain per square inch of sectional area of rim is 0.0010656 R^2 r^2, for wrought iron it is 0.0011366 R^2 r^2, for steel 0.0011593 R r^2, and for wood 0.0000888 R^2 r^2.

895. Q.—How can I find the number of cubic inches in a piece of round iron 1 inch diameter and 10 inches long?

A.—Multiply the area of the circle 1 inch in diameter in square inches by the length of the bar in inches, the product will be the number of cubic inches; in this case we have .7854 × 10 = 7.854 cubic inches.

896. Q.—I find in an arithmetic published in 1883 the following:

504, Billion 127, Million 364, Thousand 549. Hundred

Is this correct? If not, please write one billion.

A.—In the United States and France, one billion is equal to one thousand millions. In Great Britain a million of millions is equal to one billion. According to the United States and French system of numeration the above is correct; but according to the system of Great Britain a billion would be expressed thus: 1,000,000,000,000. Formerly it was the custom of pointing off the numbers in groups of six figures, but in the seventeenth century the custom prevailed of pointing the numbers in groups of three figures, and this led to the change in the meaning of the word billion.

897. Q.—What is the rule for reducing kilogrammes to pounds?

A.—A kilogramme is equal to 2.20462 pounds avoirdupois; hence, by multiplying kilogrammes by 2.20462, the equivalent number of pounds will be obtained. Thus 10 kilogrammes are equal to $10 \times 2.20462 = 22.0462$ pounds.

898. Q.—What is the difference between spiral and helical springs?

A.—A spiral spring is one which is wound around a fixed point or center, and continually receding from it like a watch spring. A helical spring is one which is wound around an arbor, and at the same time advancing like the thread of a screw; springs for safety valves are generally helical springs.

899. Q.—There is a difference of opinion on the proper way of getting the number of degrees of angle of a friction cone, some contending that the angle, as stated in degrees, means the angle of both sides added together, or the included angle, while I claim that what is meant is the angle measured on one side only, or the angle between the center line and one side. Which is right?

A.—Your idea of it is in accordance with usual practice. Where the degrees of angles of a friction cone are mentioned, the angle which one side of the cone makes with the center line is understood. Drawings of such things, when properly made, indicate between what lines the angle is measured.

900. Q.—Will you give a rule for finding the diameter of round blanks of sheet metal to be drawn by a press into a cup or dish? I want to draw up two cups to be 2½ inches outside diameter and 2¼ inches deep, the bottom of one to be flat and with sharp corners, the other with rounded corners. The metal is German silver, and is not to be drawn thinner.

A.—Mr. Oberlin Smith gave three methods of finding the

sizes of blanks. The first, or tentative method, consisted simply in a series of experiments with various blanks, until the proper one was found. The second method was by weighing the sample piece, and then, knowing the weight of the sheet metal per square inch, computing the diameter of a piece having the required area to equal the sample in weight. The third method is by computation, and the formula given is

$$x = \sqrt{d^2 + 4\,d\,h}$$

for a sharp-cornered cup. Where

x = diameter of blank,
d = diameter of cup,
h = hight of cup.

For a round-cornered cup where the corner is small, say radius of corner less than ¼ hight of cup, the formula given is $x = (\sqrt{d + 4\,d\,h}) - r$, about; r being the radius of the corner. This is based upon the assumption that the thickness of the metal is not to be altered by the drawing operation. Applying the first formula to your cup with square corner, we have $x = \sqrt{2.25'' \times 2.25'' + 4 \times 2.55'' \times 2.5''} = 5.25'' =$ diameter of blank. You do not give the radius of the corners of the round-cornered cup, but assuming it to be ¼ inch, and applying the second formula, we have

$$x = (\sqrt{2.25'' \times 2.25'' + 4 \times 2.25'' \times 2.5''})$$

$- .25'' = 5'' =$ diameter of blank.

901. Q.—A bar of iron is 8 feet long, a hole is required to be drilled in it so that the bar may work as a lever upon a pin or stud, one end of the lever must move through a distance of 3 feet, and the other end through a distance of 2.5 feet; at what distance from either end must the hole be drilled?

A.—The distances from the hole to the ends of the lever must have the same ratio as the distances through which the ends of the lever move. Hence assume the lever to be divided into $3 + 2.5 = 5.5$ parts; then each part will be $\frac{8}{5.5} = 1.4545$ feet long, and the hole must be placed at $1.4545 \times 2.5 = 3.6363$ feet from one end or $1.4545 \times 3 = 4.3636$ feet from the opposite end. The same result is obtained by the following proportion:

5.5 : 3 :: 8 : distance from end, which gives us 4.3636 feet; or 5.5 : 2.5 :: 8 : distance from the other end, which gives us 3.6363 feet.

902. Q.—What is the difference between a "square foot" and a foot square?

A.—The term "square foot," in its widest sense, is one of the units of measurement of the areas of surfaces. If, for instance, a surface is 24 feet long and 6 feet wide, it contains $24 \times 6 = 144$ square feet; if it is 24 inches long and 6 inches wide, it contains $\frac{24 \times 6}{144} = 1$ square foot. In a similar way the area of a cylindrical surface, a sphere, or of any other surface, can be expressed in square feet. The term "foot square" indicates the form of the outline of a plane surface; it indicates that the surface is bounded by four equal straight lines at right angles to each other; it also indicates the length of these lines. If, for instance, a surface 1 foot square is mentioned, it is understood that a square is meant, and that each of its sides is 1 foot long; or if a surface 20 feet square is spoken of, it is understood that this surface is bounded by four straight lines at right angles to each other, each 20 feet long. From the foregoing it will be seen that a surface 1 foot square contains 1 square foot, and a surface 20 feet square contains $20 \times 20 = 400$ square feet.

903. Q.—Can you tell me the decimal that gives the same result by multiplying as that obtained by dividing a number by 3.1416?

A.—Divide 1 by 3.1416, the quotient will be the decimal required; it is .3183+. The quotient arising from dividing unity by any number is called a reciprocal of that number. The result obtained by multiplying a given quantity by the reciprocal of a given number is always the same as that obtained by dividing the given quantity by the given number. Hence if we wish to find the decimal that gives the same result by multiplying as that obtained by dividing a quantity by a number, we have only to find the reciprocal of the latter. For instance, dividing a quantity by 5 will give the same result as multiplying it by $\frac{1}{5} = .2$.

904. Q.—I have the following formula for computing the weight of a cast-iron ball: (Diameter of the ball)$^3 \times .5236 \times .26$ = weight of ball in pounds. Is this correct?

A.—Yes, provided the diameter is in inches.

905. Q.——An air-tight and empty vessel displacing 1 cubic foot of water is placed 15 feet below the surface of the water, and two others at 10 and 5 feet respectively below the surface; what weight will each require to keep it under the water at the depths named?

A.—That depends on the weight of the vessels; they may be so heavy as to cause them to sink without any weight attached to them. Assuming that each is light enough to float, and all of equal size and weight, then the weights required to hold them under water at the depth named will be equal. To show how these weights can be computed, we will take the following example: How great a mass of solid cast iron can be supported in water by a hollow wrought-iron cylinder weighing 30 pounds and displacing 1 cubic foot of water, both bodies being completely immersed? We shall here assume that the weight of cast iron is 450 pounds per cubic foot, and water 62.5 pounds per cubic foot. The buoyant effort on the cylinder which displaces 1 cubic foot is $1 \times 62.5 = 62.5$ pounds, leaving a residue of $62.5 - 30 = 32.5$ pounds upward force to buoy the cast iron, whose volume V is unknown. The direct buoyant effort of the water on the cast iron is $V \times 62.5$ pounds, and the problem requires that this force $+ 32.5$ pounds shall be equal to the weight of the cast iron which the cylinder is to support. Hence we have $V \times 62.5 + 32.5 = V \times 450$; this reduces to $32.5 = 387.5\,V$; hence $V = \frac{32.5}{387.5} = .083$ cubic foot, and the required weight of the cast iron will be $.083 \times 450 = 37.35$ pounds.

906. Q.—Does the distance between two speed cones make any difference in computing the diameters of their steps.

A.—Yes.

907. Q.—We have two speed cones with two steps to each; the diameters of the steps on one of the cones are 4 inches and 6 inches; the latter drives a step pulley 14 inches diameter on the second speed cone. What must be the diameter of the step on this second speed cone, so that when connected with the 4-inch step on the first cone the tension of the belt will not be changed?

A.—15⅝ inches.

908. Q.—Please give me a rule for reducing a decimal fraction to a common fraction.

A.—Place a cipher (0) below each digit in the decimal, and place a 1 in front of the ciphers; the result will be a common fraction; reduce this to its lowest terms by the ordinary rules of arithmetic.

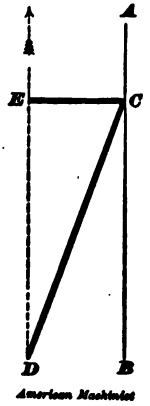
909. Q.—A horizontal tank, 18 feet long and 60 inches diameter, is filled two-thirds with water; what will be the hight of the water in the tank?

A.—The water surface divides the cross-sectional area into two segments. We shall first find the hight of the segment above the surface of the water. The best way to accomplish this is by means of a table of areas of circular segments, the diameter of the circle being equal to 1. This table will be found in Trautwine's, Kent's and many other engineer's pocket-books. The rule is: Divide the area of the segment of the corresponding circle, look for quotient in the column of areas in the table, take out the corresponding hight, and multiply it by the diameter of the circle; the product will be the required hight of the segment. In your example, we have a circle 60 inches diameter; its area is 2,827.4 square inches. The area of the segment above the water level is one-third of this, $\frac{2827.4}{3} = 942{,}466$ square inches; dividing this by the square of the diameter ($60 \times 60 = 3{,}600$), we have $\frac{942.466}{3\,600} = 0.2618$. Looking for this number in the column of areas in the table, we find a corresponding hight of .367, and multiplying this by the diameter of the circle, we have $.367 \times 60 = 22.02$ inches for the hight of the segment above the surface of the water. The hight of water from the bottom of the tank will be $60 - 22.02 = 37.92$ inches. From this it will be seen that the length of the tank does not enter into the computation.

910. Q.—In the accompanying sketch, $A\,B$ represents a vertical line, $C\,D$ represents a door hinged at C, and when closed forming an angle of about 25 degrees with $A\,B$. The dotted line represents a chain used for opening the door. Will it require a greater pull to start the door from its present position when the chain is fastened at D than when fastened at E? The line $E\,C$ represents a bar firmly attached to the door; the points E and D are

in the same vertical line, or at the same distance from the line *A B*.

A.—There is no difference in the pull of chain at starting, or so long as the points of application *E* and *D* are in the same vertical line; but as soon as the door begins to move, the point



E will approach the line *A B* and the point *D* will recede from the line *A B*, and therefore the pull at *E* will be constantly increased, while at *D* the pull will constantly decrease.

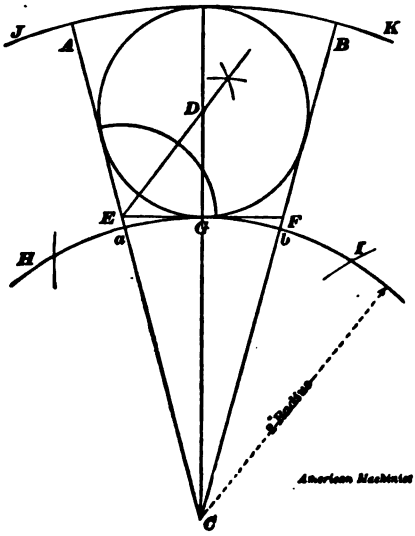
911. Q.—Does the angle *E C D* make any difference so long as the points *E* and *D* are at the same distance from the vertical line *A B*?

A.—No.

912. Q.—Kindly give a method or rule for finding the diameter of balls for a ball bearing. The balls are to touch each other, and lie in a plane perpendicular to the axis of the bearing, the number of balls is given.

A.—To make this plain, we shall take the following example: The journal is 4 inches diameter; there are to be 12 balls around it; the balls are to touch each other; what will be the diameter of the balls? In the accompanying sketch, let *H I* be a portion of the circumference of the journal 4 inches diameter, divide the whole circumference into 12 equal parts, and thus obtain the arc *a G b* = 1-12th of the whole circumference; bisect this arc

at G, and through this point and the center C of the journal draw the straight line $C\,D$; also through the points C and a draw the line $C\,A$, and through the points C and b draw the line $C\,B$; through G on the circumference $H\,I$ draw the line $E\,F$ perpendicular to $C\,D$, terminating in the point E on the line $C\,A$, and in F on the line $C\,B$. Bisect the angle $A\,E\,F$ by the line $E\,D$, cutting the line $C\,D$ in the point D; this point will be the center of the ball, and $D\,G$ will be its radius. This is a graphical solution of the problem, and it consists simply of

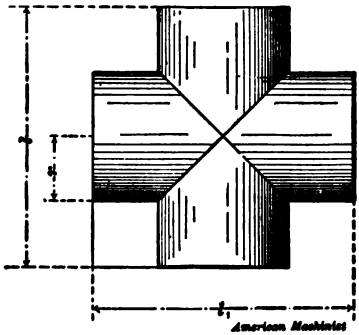


finding the center of a circle which shall be tangent to the lines $C\,A$, $C\,B$ and $E\,F$. From this construction we can find the diameter of the ball by computation as follows: The angle $A\,C\,B$ is equal to $\frac{360}{12} = 30$ degrees, hence the angle $A\,C\,D$ is equal to 15 degrees; the sine of an angle of 15 degrees is .2588, consequently the line $E\,G$ is (.2588 $\times$ radius of 2 inches $=$) .5176 inch long. The angle $A\,E\,G$ is one of 105 degrees, hence the angle $D\,E\,G$ is one of 52½ degrees; the tangent of an angle

of 52½ degrees is equal to 1.3032, consequently the length of the line $D\,G$, which is the radius of the ball, is equal to .5176 × 1.3032 = .6745, and the diameter of the ball will be 1.349 inches.

913. Q.—Please give me a formula for computing the volume of two cylinders of equal diameters, and intersecting each other as shown in the accompanying sketch.

A.—Add together the lengths of the two cylinders, from this sum subtract two-thirds of the radius, and multiply the remainder by the cross-sectional area of the cylinder. Expressing this rule in symbols, we have $\pi r^2 (l + l_1 - \frac{2}{3} r)$ = volume of both cylinders, in which r = radius of cylinders and l = length of



the other cylinder. If the radius is taken in inches, and the length in inches, the volume will be in cubic inches.

914. Q.—In the accompanying sketch the line $c\,d$ is perpendicular to the radius $o\,c$, the arc $c\,e$ is tangent to $c\,d$ at c, and is 1,000 feet long, and the vertical hight h is 400 feet; it is required to find the length r of the radius.

A.—The angle θ and radius r can be found approximately by the following method; first find the chord A of double the angle θ by the following formula:

$$A = \tfrac{8}{5} L + \sqrt{\tfrac{16}{25} L^2 - \tfrac{64}{15} h^2},$$

in which A = length of chord of double the arc, L = length of double the given arc, and h = the hight of this arc, as indicated in the sketch. From the above formula we get for the length

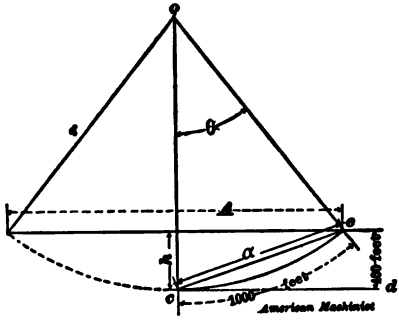
$A = 1{,}770.15$ feet. The next step will be to find the chord a of one-half the arc of 2,000 feet by the following formula:

$$\sqrt{\left(\frac{A}{2}\right)^2 + h^2} = a; \qquad (2)$$

from this we get $a = 971.26$ feet. The data as found above will now enable us to find the radius from the following formula:

$$\frac{a^2}{2h} = r. \qquad (3)$$

This gives us 1,179.18 feet for the radius. The sine of θ is equal to $\frac{\frac{1}{2}A}{r} = .7505$, which corresponds to angle of 48° 39′ nearly. It should be remembered that these results are close approxima-



tions only; the radius as found above is a little too great, but will probably be near enough for your purpose. The above method gives very close results when twice the angle θ does not exceed 30 degrees.

915. Q.—Supposing the figure in the sketch to be divided into two portions of equal area by the line $c\,d$, how can I, by algebra, find the lengths of $a\,b$ and $c\,d$?

A.—For convenience we first reduce the total length to inches; 30 feet = 360 inches. The total area of the figure is $\frac{18+9}{2} \times 360 = 4{,}860$ square inches, and the area of the divided portions will therefore be $4{,}860 \div 2 = 2{,}430$ square inches. Let x = the length of $c\,d$, and y = length of $a\,b$, then the length of

$b\,e$ will be $360 - y$. As the two portions are to have equal areas, we at once have the equation:

$$\frac{x+9}{2} \times y = \frac{x+18}{2} \times (360 - y) \qquad \text{A}$$

which, performing the operations indicated, becomes:

$$x\,y + 9\,y = 360\,x - x\,y + 6{,}480 - 18\,y,$$

and transposing and adding we have:

$$27\,y + 2\,x\,y - 360\,x = 6{,}480. \qquad \text{B}$$

Taking the first member of the equation A and its value, we have:

$$\frac{x+9}{2} \times y = 2{,}430 \qquad \text{C}$$

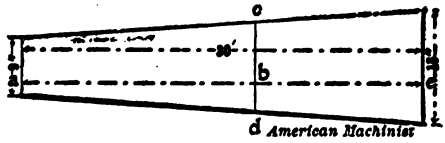
which we reduce to $x\,y + 9\,y = 4{,}860$, and thus obtain the value of y:

$$y = \frac{4{,}860}{x+9} \qquad \text{D}$$

This value we substitute in equation B, which gives us:

$$\frac{4{,}860 \times 27}{x+9} + \frac{4{,}860 \times 2\,x}{x+9} - 360\,x = 6{,}480$$

which clearing of fractions, etc., becomes: $131{,}220 + 9{,}720\,x -$



$360\,x^2 - 3{,}240\,x = 6{,}480\,x + 58{,}320$, which reduced gives us:

$$4\,x^2 = 810,$$

$$x^2 = 202.5,$$

$$x = 14.23 \text{ inches};$$

and substituting this value in equation D, we have:

$$y = \frac{4{,}860}{14.23 + 9}$$

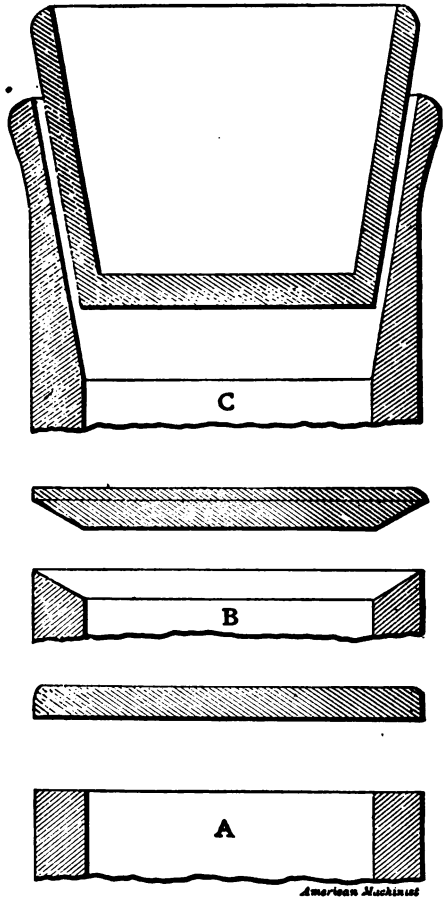
$$y = 209.21 \text{ inches}.$$

These values of x and y give the required result very closely, as we find by substituting them in equation C:

$$\frac{14.23 + 9}{2} \times 209.21 = 2{,}429.97.$$

916. Q.—Is it true that a valve with a flat seat will give more opening for the same lift than a valve with a bevel seat?

A.—It is true. The sketch will show the difference at a glance. The three valves are represented with the same lift. *A*, with the flat seat, has an opening equal to the full capacity



of the circle. *B*, with a seat beveled 30 degrees, shows a little reduction of the passage, but generally not enough to be taken

into account; and if this angle is not exceeded, as it seldom should be in practice, the valve may be considered equal in capacity to the flat-seated valve. The valve *C*, with a more acute angle, shows for itself the reduction of area. If our correspondent had taken the trouble to make a few marks, as we have done, he would have settled the question for himself for all his life, while under the present circumstances it is possible that he may forget and have to ask again.

917. Q.—What is meant by the terms "modulus of elasticity" and "coefficient of elasticity," as used in books treating on the strength of materials?

A.—Both terms mean the same thing. Elasticity is the name given to the property which most materials have, to a certain extent, of regaining their original form when the external forces are removed. Up to a certain limit, called the elastic limit, experiments have shown that the elongation of a bar of any material subjected to a tensile force is approximately proportional to that force. The same law holds good when the bar is subjected to a compressive force. Now the modulus of elasticity for tension or compression is the number obtained by dividing the stress per unit of cross-sectional area by the corresponding relative increase or decrease of length. It is customary to take one square inch for the unit of area, and the stress in pounds; hence, to find the stress per square inch, we simply divide the external force in pounds acting on the bar by the cross-sectional area of the bar in square inches; or in symbols $S = \frac{P}{A}$, in which S denotes the stress per square inch, P the external force in pounds, and A the area of the section in square inches. The increase or decrease of the length must be taken per unit of length of the bar; if the total change of length is given in inches we must divide this by the length of the bar in inches; or, if the change of length is given in feet, we must divide this by the length of the bar in feet; the result will be the increase or the decrease per unit of length, according as the bar is subjected to tensile or compressive force. In symbols we have $e = \frac{c}{l}$, in which e denotes the change of length per unit of length of the bar, c the total change of

length, and l the original length of bar. If now we denote the modulus of elasticity by E, we have, according to its definition,

$$E = \frac{P}{A} \div \frac{c}{l}$$

which reduces to

$$E = \frac{P \times l}{A \times c} \qquad (a)$$

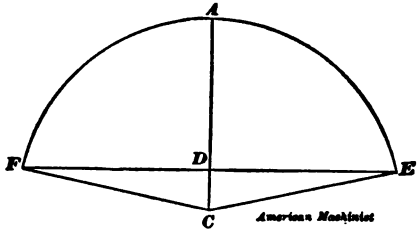
To show the application of the formula, we will take the following example: A bar of wrought iron was subjected to a tension of 5,000 pounds; its cross-sectional area is .5 square inch; its original length, 6 feet; during tension it was found that its total length was 6,002 feet; find the modulus of elasticity. Here we have $P = 5{,}000$, $A = .5$ inch, $l = 6$ feet, and $c = .002$ foot. Substituting for the symbols in formula (a) their values, we have

$$E = \frac{5{,}000 \times 6}{.5 \times .002} = 30{,}000{,}000 \text{ pounds}$$

per square inch. This is modulus of elasticity of wrought iron in tension; the modulus for compression is found in precisely the same way.

918. Q.—Kindly give me a solution of the following problem: The hight of a segment of a circle is 23 inches, the radius of the circle is 30 inches, find the area of the segment.

A.—To find the area of this segment we first find the area



of the sector $A\,F\,C\,E$. and from this subtract the area of the triangle $F\,C\,E$; the result will be the area of the segment. The first step will be to find the length of $D\,E$ which is equal to one-half the chord. The hight $A\,D$ of segment is 23 inches, consequently the altitude $D\,C$ of the triangle $F\,C\,E$ will be $30 - 23 = 7$ inches. Now to find the length of $D\,E$, square the

length of $C\,D$ and subtract this from the square of the radius $C\,E$, and find the square root of the remainder, the result will be the length of $D\,E$; thus

$$\sqrt{30^2 - 7^2} = 29.17 \text{ inches,}$$

which is the length of $D\,E$. The next step will be to find the number of degrees in the angle $F\,C\,E$; to do so, we first find the sine of the angle $D\,E$ by the radius $C\,E$, thus

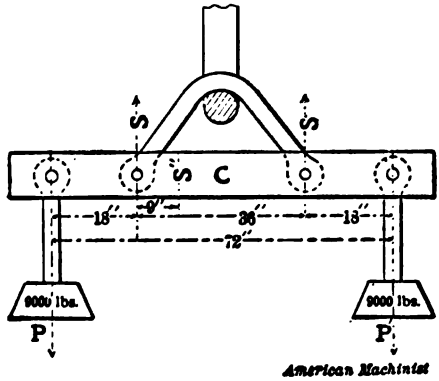
$$29.17 \div 30 = 0.9723,$$

which is the sine of the angle $D\,C\,E$; looking for this sine in a table of natural sines, tangents, etc., which can be found in any engineer's pocket-book, we find that the number of degrees corresponding to this sine is 76; consequently the angle $F\,C\,E$ will contain $76 \times 2 = 152$ degrees. We are now in a position to find the area of the sector $A\,F\,C\,E$, which is done by multiplying the area of the whole circle by 152, and dividing the product by the number of degrees in the whole circle, namely 360. The area of a circle 60 inches diameter is equal to 2,827.4 square inches; hence the area of the sector will be equal to $\frac{2,827.4 \times 152}{360} = 1,193.79$ square inches. The area of the triangle $F\,C\,E$ is equal to $29.17 \times 7 \times 204.19$ square inches, and the required area of the given segment will be $1,193 - 204.19 = 989.6$ square inches.

919. Q.—What are the bending moments at S and C in the sketch of a beam supported and loaded as shown, and how are they calculated?

A.—In cases of this kind, determine the magnitude of the reactions of the support and consider them as applied forces acting upward. In the present case it is obvious that reactions S and S' are each equal to P and P', or 9,000 pounds. To find the bending moment at any section consider the forces which act downward as positive and those which act upward as negative, and take the algebraic sum of the moments of all forces on one side of the section. At S or S' the moment is that of P or P' only, or $18 \times 9,000 = 162,000$ inch-pounds. At C the moment of P is $36 \times 9,000 = 324,000$ inch-pounds, and that of S is $18 \times 9,000 = 162,000$ inch-pounds. The moment of P is positive and that of S negative, the algebraic sum being 162,000 inch-pounds—the resultant moment at C. Note that the same

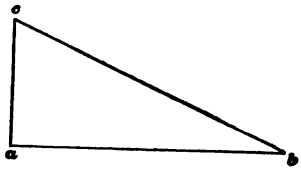
moment will be obtained for all points between S and S'. Thus take S'' where the moment of P is $27 \times 9{,}000 = 243{,}000$ inch-



pounds, while the moment of S is $9 \times 9{,}000 = 81{,}000$ inch-pounds, the resultant being as before, 162,000.

920. Q.—How can I find the angle in degrees of different tapers? For example, how many degrees are there in the angle formed by the two lines $a\,b$ and $b\,c$, the line $a\,b$ being 12 inches long, and the line $a\,c$ perpendicular to $a\,b$ is $\frac{3}{8}$ inch long?

A.—Divide the length of $a\,c$ by the length of $a\,b$; the quotient



will be the tangent of the angle. Thus, remembering $\frac{3}{8} = .375$, we have $\frac{.375}{12} = .03125$ for the tangent. Look for this in a table of natural tangents, sines, etc., given in any good engineers' pocket-book, and opposite to this number you will find the number of degrees in the angle; in this case 1° 47′, very nearly.

921. Q.—A beam 30 feet long, weighing 300 pounds, is to be carried by three men; one man at the end, and the other two having a

bar for it to rest on. How far from one end must the bar be placed to make the weight equal on each man?

A.—In examples of this kind we may assume that the whole weight of the beam is concentrated at its center of gravity; and and if the beam is of equal cross-section throughout, its center of gravity will be at the center of the beam. Assuming that the beam is of equal cross-section throughout, then the weight supported by the single man at the end of the beam, multiplied by the distance between this man and the center of gravity of the beam, must be equal to the sum of the weights supported by the other two men multiplied by the distance from the center of gravity of the beam to the two men. Now since the bar is 30 feet long and its center of gravity at 15 feet from either end, and each man had to support 100 pounds, we have the following rule: Multiply the weight supported by one man by the distance between him and the center of gravity, divide this product by the weight supported by the other two men; the quotient will be the distance between the center of gravity and the two men. Thus:

$$\frac{100 \times 15}{200} = 7\frac{1}{2} \text{ feet,}$$

which is the distance between the center of the beam and the two men.

922. Q.—Is the diedral angle in geometry a plane or a solid angle; also, why is it?

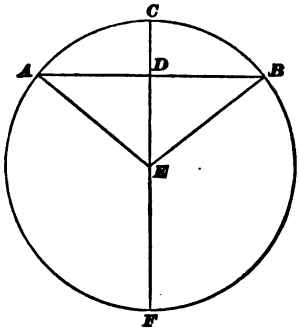
A.—It is neither. A diedral angle is the angular space lying between two planes which meet each other. The planes are called faces of the angle, and their line of meeting is called the edge. The measure of a diedral angle is the same as that of a plane angle formed by two straight lines, one lying in each face, and both perpendicular to the edge at the same point. Diedral angles, like plane angles, may be either right, acute or obtuse. A solid angle is the angular space contained by more than two planes which meet at the same point, and not lying in the same plane. A plane angle is a portion of a plane lying between two straight lines meeting in a common point. The two straight lines are called the sides of the angle, and the common point the vertex.

923. Q.—What is the difference between a segment and a sector?

A.—A segment is a part of a circle included between an arc and its chord. A sector is a part of a circle included by an arc and the two radii drawn to its extremities.

924. Q.—What is the area of a segment of a circle; the diameter of the circle is 80 inches, and the hight of the segment is 31 inches.

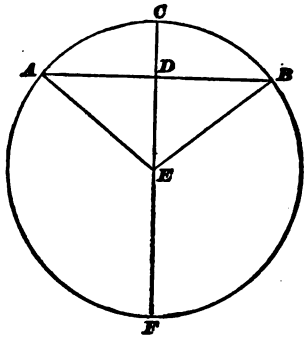
A.—In the accompanying figure, the line $A\,B$ represents the chord of the segment, and $A\,E$ and $B\,E$ the two extreme radii of the sector $A\,C\,B\,E$. It will be at once apparent that the area of the segment $A\,C\,B$ is equal to the area of the sector $A\,C\,B\,E$ minus the triangle $A\,E\,B$. Hence we have the following rule: Find the area of the corresponding sector, and also of the triangle formed by the chord of the segment and the two extreme radii of the sector; subtract the latter from the former, the



remainder will be the area of the segment. The area of the sector is found as follows: Find the area of the whole circle, then write the proportion, as 360 is to the number of degrees in the sector, so is the area of the circle to the area of the sector. Applying these rules, we have for the area of the sector 2,150.26 square inches; for the area of the triangle $A\,E\,B$ we have 350.73 square inches, which gives us for the area of the segment 2,150.26 — 350.73 = 1,799.53 square inches.

925. Q.—I wish you would give me the shortest and correct way of computing the area of a segment of a circle when its chord and hight are given without any other dimensions; for example, to find the area of the steam space above the water line in a cylindrical boiler.

A.—The rule for finding the area of a segment with the dimensions as given above is not a very short one. It involves considerable labor, although not difficult for anyone who has a fair knowledge of geometry. To make the computation plain we will take the following example: The hight *C D* of the segment *A B C* is 14 inches, its chord *A B* is 43.6 inches; find its area. The first step will be to find the radius *A E*. To do so, square one-half the chord *A B* and divide the result by the hight; the quotient will be the distance *D F*. Adding *C D* to this we have the diameter. One-half the chord is equal to 21.8 inches, and $\frac{21.8 \times 21.8}{14} = 33.94$, say 34 inches for the distance *D F;* adding 14 to this we have 48 inches for the diameter



of the circle or 24 inches for the radius *A E*. The next step will be to find the number of degrees in the angle *A E B;* to do this, we find the sine of half this angle, and then look for this in a table of natural sines, tangents, etc., found in any of the engineer's pocket companions, and opposite to it we will find the number of degrees in the angle *A E D;* this will be the number of degrees in the angle *A E B*, or the angle of the sector *A E B C*. To find the sine of the angle A E D, divide one-half the chord by the radius; hence $\frac{21.8}{24} = .90833$ is the sine, the corresponding number of degrees is 65.17, and $65.17 \times 2 =$ 130° 34′ is the angle *A E B* of the sector. The next step will be to find the area of the sector *A E B C* by the following rule of

proportion: As 360 degrees is to the number of degrees in the sector so is the area of the circle to the area of the sector. The area of a circle 48 inches in diameter is 1,809.6 square inches; hence we have

$$360 : 130° 34' :: 1{,}809.6 : x$$

reducing the degrees to minutes we have

$$21{,}600 : 7{,}834 :: 1{,}809 : x$$

from which we get 656.31 square inches for the area of the sector. From this we must subtract the area of the triangle $A\,E\,B$, which is $\frac{43.6 \times 10}{2} = 218$ square inches; hence the area of the segment will be $656.31 - 218 = 438.31$ square inches.

926. Q.—Please give me a rule for finding the hight of a segment of a circle whose area is equal to ⅓ of the area of the circle; or, in other words, let it be required to divide a circle into three parts of equal areas; what will be the hight?

A.—Multiply the diameter of the circle by .3675; the product will be the hight $a\,b$ of the segment.

927. Q.—Give a simple rule or formula for finding the chord of a circle, the circle being divided into a number of equal parts.

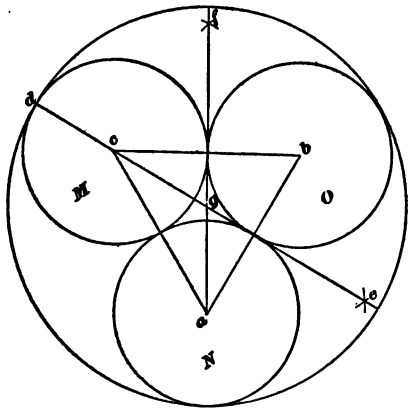
A.—We understand that you want a rule for finding the chords of arcs containing a certain number of equal divisions on the circumference. This is best explained by giving an example. Let the radius of the circle divided be 7 inches, and the circumference of this circle divided in 24 equal parts. To find the chord of the arc equal to one of these parts, divide 360 by 24; this gives us $360 \div 24 = 15$ degrees for the angle at the center subtended by an arc of 1-24th part of the circumference. Now find the sine of half this angle—that is, the sine of 7½ degrees, which is given in any table of natural sines, and tangents to the radius of 1; it is .1305; multiply this by the radius, the result will be the length of one-half the chord; thus $.1305 \times 7 = .9135$ inch for one-half the chord; d $.9135 \times 2$ for the length of the whole chord. In the same way the length of the chord for any number of divisions on the circumference can be fund. Thus, find the chord of an arc containing four of the equal divisions on the circumference. We have found that one division contains 15 degrees, consequently four divisions will contain $15 \times 4 = 60$ degrees; the sine.

of one-half this angle—that is, the sine of 30 degrees—is .5. Multiplying this by the radius we have $.5 \times 7 = 3.5$ inches for one-half the length of chord, and $3.5 \times 2 = 7$ inches for the length of the whole chord.

928. Q.—What is the rule or method for dividing a ring into three equal parts; say, for instance, the ring is 22 inches outside diameter and 19 inches inside diameter; the width of the ring is ⅜ inch?

A.—It is proved in geometry that the side of a regular hexagon is equal to the radius of the circumscribed circle. Hence, set a pair of compasses to the radius of the outer circumference and lay this distance off six times on the outer circumference; this will divide it exactly into six equal parts. Through the points of division draw radial lines terminating in the inner circumference; this will divide the ring into six equal parts; two of these will be one-third of the ring. The same result could have been obtained by laying off the radius of the inner circumference on the latter, and then drawing radial lines to the outer circumference; but by following the first method more accurate results are generally obtained. The thickness of the ring has nothing to do with the solution of the problem.

929. Q.—Please give me the graphical construction for finding the center and radius of a circle which will circumscribe three smaller circles of equal diameter touching each other.



A.—Let *M, N, O* be the given circles of equal diameter touching each other. Join their centers *a, b* and *c* by straight lines; these will form an equilateral triangle. Bisect any side of this triangle, say *a b*, by a perpendicular *d e*, cutting the circumference of *M* in the point *d*. Again, bisect any other side of the triangle, say *b c*, by a perpendicular *a f*, cutting *d e* in the point *g*. This point *g* will be the center of the circumscribing circle, and *g d* will be its radius. In a similar way the center may be found of a circle circumscribing any three given circles of equal diameters, whether they touch each other or not.

930. Q.—How can I find the diameter of a hexagon across the corners when the distance from side to side is known? For instance, I wish to mill a hexagonal nut 1¾ inches from side to side; how large must the blank be turned to mill to those dimensions and leave sharp corners?

A.—Multiply the distances over the flat sides by 1.155. In the case mentioned, the size will be $1.75'' \times 1.155 = 2.021''$.

931. Q.—Which is the best method of calculating the rise of a segment of a circle whose area is $\frac{2,157}{2.157}$ of the area of the circle? Diameter of circle, 78 inches.

A.—Reduce the fraction to a decimal, which is equal to 0.35. Multiply the area of the circle, which is 4,778.36 square inches, by 0.35; the product will be the area in square inches of the segment, and is equal to 1,672.426 square inches. Divide this area by the square of the diameter,

$$\frac{1,672.426}{78 \times 78} = .274:$$

look for this quotient in a table of areas of circular segments in the column marked areas, and opposite to it you will find the decimal .381; multiply this decimal by the diameter of the circle, $.381 \times 78 = 29.71$, which is the hight of the segment in inches.

932. Q.—Please inform me how to find the length of a chord of a circle when its distance from the diameter is given. For example, the diameter of the circle is 3 inches; distance from the diameter to the chord, .2 of an inch; what is the length of the chord?

A.—Square the given distance from the diameter to the chord, also square the radius of the circle; subtract the former

from the latter, and extract the square root from the remainder, and multiply the result by 2. Thus the square of .2 is .2 × .2 = .04; the square of the radius is 1.5 × 1.5 = 2.25. And 2.25 — .04 = 2.21. The square root of 2.21 is 1.486, and 1.486 × 2 = 2.972 inches, which is the length of the required chord.

933. Q.—Why does the shadow of the moon cast on the earth by the sun during an eclipse travel across the earth approximately from west to east instead of from east to west?

A.—If you imagine the moon to get into position and then to stand still, the rotation of the earth about its axis would cause the shadow to travel from east to west. On the contrary, if the rotation of the earth on its axis were to stop, the revolution of the moon about the earth would cause the shadow to travel from west to east as it does. With both earth and moon in motion, the movement of the shadow is the resultant of the two, and the effect of the moon's motion predominates over that of the earth, as it is relatively the faster of the two.

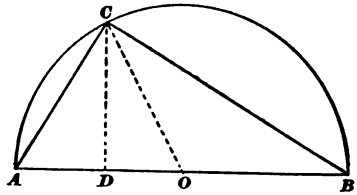
934. Q.—How can I divide a circle into degrees, as I have no protractor?

A.—It all depends upon what instruments you actually have and what kind of a fellow you are. The problem of course is, to divide the circumference of a circle into 360 equal divisions. Draw as big a circle as possible. If your work does not require a big circle, you can draw one, all the same, outside of it. As you have drawn a circle, it must be that you have a pair of compasses, or their equivalent. Without changing the set of the compasses, you can divide the circle into six parts, or sectors of 60 degrees each. Bisect each sector twice—don't ask how to do this—and you will then have the circle divided up into sectors of 15 degrees each. A simpler way to get to this point is by the use of a T-square or straight-edge in connection with the two triangles of 30 and 45 degrees, which all draftsmen now use. Now divide one of these sectors first into five smaller sectors, and then each of these into three. You will then have 15 single degrees of the circle. To save the trouble of going through the same operation all around the circle, you can take a piece of paper wide enough to cover the 15 degrees and stick a pin through it in the center of circle, and trim off the edge of

it to the circle. You can then mark the edge to correspond to the fifteen 1-degree spaces already obtained, and moving the paper to the next sector, you can mark it off, and so on all around the circle. The accuracy of the work will depend upon the care with which it is done and the sharpness and precision of the marks used. It can in no case be expected to be nearly as correct as a machine-graduated protractor. If the radius of the circle is 12 inches, the length of arc for 1 degree will be 0.20944 inch.

935. Q.—Please inform me how to solve the following problem: The hypothenuse $A\,B$ of a right-angled triangle is 22 inches long, the area of the triangle is 100 square inches; find the lengths of the sides $A\,C$ and $B\,C$.

A.—A right-angled triangle can always be inscribed in a semi-circle whose diameter is equal to the hypothenuse of the



triangle, as shown in the accompanying figure. The first step will be to find the length of the line $C\,D$ drawn from C perpendicular to the hypothenuse $A\,B$. Since the area of the triangle is equal to the product obtained by multiplying the length of $A\,B$ by half the length of the perpendicular $C\,D$, we have for the length of $C\,D$

$$\frac{100 \times 2}{22} = 9.09 \text{ inches};$$

Draw the radius $C\,O$; we then have a right-angled triangle $C\,D\,O$ whose hypothenuse $C\,O$ is 11 inches, and the length of the side $C\,D$ is 9.09 inches. From this data we can easily compute $D\,O$ by subtracting the square of $C\,D$ from the square of $C\,O$, and finding the square root of the remainder, which gives us

$$\sqrt{11^2 - 9.09^2} = 6.19 \text{ inches for } D\,O.$$

Adding $D\,O$ *to* $O\,B$ we have $6.19 + 11 = 17.19$ inches for the ment $D\,B$, and subtracting $D\,O$ from $O\,A$ we have $11 - 6.19$

= 4.81 inches for the segment $A\,D$. Now, since $B\,C\,D$ is a right-angled triangle, and since we know the lengths of $C\,D$ and $D\,B$, the side $C\,B$ is easily found by simply adding the square of $B\,D$ to the square of $C\,D$ and extracting the square root of the sum, which gives us

$$\sqrt{17.19^2 + 9.09^2} = 19.44 \text{ inches}$$

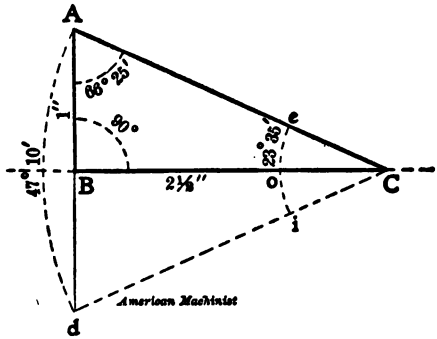
for the length of the side $B\,C$. The length of the side $A\,C$ is found in a similar way. $A\,C\,D$ being a right-angled triangle whose sides $A\,D$ and $D\,C$ are known, we have

$$\sqrt{4.81^2 + 9.09^2} = 10.24 \text{ inches}$$

for the length of the side $A\,C$.

936. Q.—Given a right-angled triangle with base 2½ inches and hight 1 inch, how many degrees are there in each of the other two angles, and how are they found?

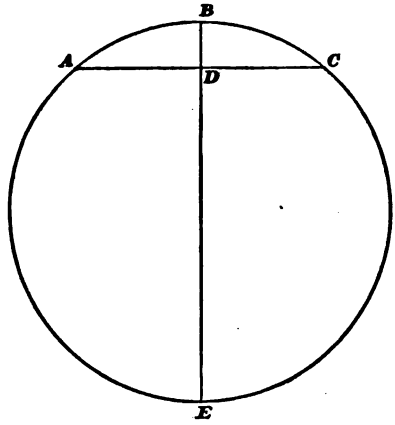
A.—Let $A\,B\,C$ be the triangle. To ascertain the angle $A\,B\,C$, assume that $B\,C$ is the radius of a circle, $A\,B$ one-half of the chord of an arc $A\,d$ of that circle. As $A\,B$ is 1 inch, $A\,d$ is 2 inches; and as $B\,C$ is 2½ inches, 2½ : 2 :: 1 : .8; then from



a table of chords we find that the angle for a chord of .8, where the radius is 1, is 47° 10′, and one-half the angle, or the angle $A\,C\,B$, is therefore 23° 35′. As the sum of the three angles of a triangle is 180 degrees, and as one of the angles in this case is 90 degrees, we have 90 degrees left for the sum of the other two angles, and 90° — 23° 35′ = 66° 25′, which is the angle $B\,A\,C$.

937. Q.—How can I compute the diameter of a circle from a given segment?

A.—Let *A B C D* be the given segment, its hight *B D* and the length of the chord *A C* being known. Square one-half the length of the chord and divide the product by the hight *B D*, the quotient will be the length of *D E;* add to this the hight *B D*, the sum will be the diameter *B E* of the circle. If, for instance, the hight *B D* is 3 inches, and *D C*, one-half the chord, is 6.4 inches, then we have for the square of *D C*



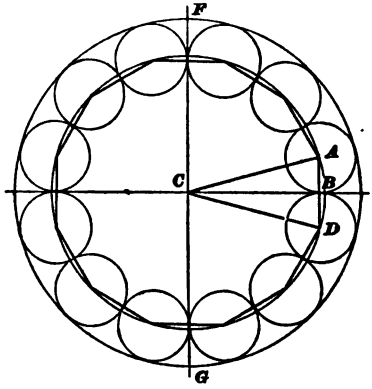
$$6.4 \times 6.4 = 40.96.$$

Dividing this by *B D* = 3 inches, we have $\frac{40.96}{3} = 13.65$ inches for the length of D E, and $13.65 + 3 = 16.65$ inches for the diameter *B E*.

938. Q.—Please give us a reliable rule for determining the diameter of a circle into which a certain number of rings will fit on its inside. For instance, what is the diameter of a circle into which twelve ½-inch rings will fit, as per sketch?

A.—To make this rule plain, let us assume that we have found the diameter of the required circle, and have drawn the rings inside of it. Join the centers of these rings by straight lines, as shown; we then obtain a regular polygon with twelve

sides, each side being equal to the diameter of a given ring. It is now easy to be seen that all we have to do is to find the diameter of a circle circumscribed about this polygon and add the diameter of one ring to it; the sum will be the diameter of the circle into which the rings will fit. Through the centers A and D of two adjacent rings draw the radii $C\,A$ and $C\,D$. Since the polygon has twelve sides, the angle $A\,C\,D$ will be $\frac{360}{12} = 30$ degrees; and one-half of this angle—that is, $A\,C\,B$—will contain 15 degrees. Now, one-half of the side $A\,D$ is equal to $A\,B$. We can now give the following proportion: The sine of the



angle $A\,C\,B$ is to $A\,B$ as 1 is to the required radius. From this we get the following rule: Divide $A\,B$ by the sine of the angle $A\,C\,B$; the quotient will be the radius of the circumscribed circle; add to the corresponding diameter the diameter of one ring; the sum will be the required diameter $F\,G$. To show the application of this rule, we will work out the example. The sine of the angle $A\,C\,B$ is .258819; the length of $A\,B$ is .25; hence the radius $C\,A$ is $\frac{.25}{.258819} = .965$ inches, and the diameter $F\,G$ is $.965 \times 2 + .5 = 2.43$ inches.

Processes.

939. Q.—I have been dipping iron in acid solution of sulphate of copper, but the copper scales off in places. What is wrong?

A.—We should judge that the iron is not properly cleaned. Try immersing the articles for ten minutes in water containing about 2 per cent. muriatic acid, then thoroughly scrub with a wire brush and sand, after which wash in clean water till all traces of acid are removed.

940. Q.—Is there any way of making babbitt metal remain in cast-iron boxes which have been bored? I have tried tinning them and have tried it with rosin, but the metal seems to shrink away from the boxes after having cooled, leaving it loose.

A.—This difficulty is partially overcome by previously heating the boxes, so that they also will shrink. The heating also greatly facilitates the soldering or the metallic adhesion of the babbitt to the tinned surface of the iron. It is best, however, to expand the metal within the boxes after pouring by means of forcing a drift through them, or by hammering after pouring the box, and this is the method resorted to where the best results are obtained.

941. Q.—How can I securely fasten, so that it will stand hard work, soft sheet rubber, about ½ inch thick, to wooden rolls which are from 4 to 6 inches in diameter?

A.—A cement made as follows will fasten rubber to wood, and make it impervious to the action of gases or fluids: Soak pulverized gum shellac in ten times its weight of strong ammonia. Rubber cements for this purpose can be obtained at almost any rubber store, and it is probable that some of the tire cements used by wheelmen will answer.

942. Q.—I find that rubber which has been dissolved in benzine, and then used as a coating on various articles, does not harden satisfactorily. How can it be hardened, or its stickiness removed, for use in the manner spoken of?

A.—Your difficulty is precisely what Goodyear removed in

his wonderful discovery of vulcanized rubber, which is essentially hardening and removing the stickiness of caoutchouc or rubber (for the coating of fabrics and the manufacture of articles for use) by a process of treating it with sulphur at a high temperature.

943. Q.—I have seen numbers of small brass screws about ⅛ inch long, and the size of common pins, that were black on the surface, and the color seemed to be the product of chemical action on the surface of the metal rather than caused by the use of black paint or japan. Can you tell me how to produce a like result—a black or dark color on the surface of the metal, on small brass screws the size of common pins?

A.—Into 6 gallons muriatic acid put 2 pounds yellow arsenic, and 1 pound black oxide of iron. Have the pieces thoroughly clean and dry and dip them until the desired shade is produced, then rinse them in clear water and dry in fine sawdust. A much smaller quantity of the chemicals may of course be used if the approximate proportions are secured.

944. Q.—How can I boil sweet oil? I have tried placing it in a vessel over a fire, but after it became quite hot, but not enough to boil, the oil would take fire. I have also tried placing in a water bath but with no better result. By giving instructions how I may overcome my present trouble, with a receipt that will produce the desired effect, you will greatly oblige me.

A.—You do not state the quantity of oil you wish to boil at one time, but from the following you will be able to accomplish what you desire: To boil a small quantity of oil, place it in a test tube (glass) and hold or suspend it over a spirit lamp. Apply the heat very slowly. To boil a quart or so, put the oil in a glass vessel—a pickle jar will do very well—and follow the above directions. For large quantities it should be put into an iron vessel or kettle or tube with a close-fitting hood to cover the top, for conveying the vapor away either to a chimney or so far that there will be no danger of its taking fire. It requires about 420 degrees Fahr. to boil sweet oil, and care should be observed not to raise the temperature too rapidly or the oil will be burned. When brought to a boiling point the heat should be carefully regulated.

945. Q.—We have a cam roll on a machine for compressing shoe heels

which has to withstand a pressure of 25 tons; the roll makes about 50 revolutions per minute. It is made of tool steel and hardened, as machine steel case-hardened did not last long. Will it be possible to use a roll of tool steel hardened and then shrunk on to a shaft of machine steel? Can we get the roll on tight enough without drawing the temper? Will the pressure have a tendency to loosen the roll from the pin? The roll is 6 inches diameter and 3 inches wide, the journals of the shaft are 4 inches diameter and 6 inches long and run in half boxes of cast iron. The cam revolves in an oil bath and has journals of the same dimensions as the roll.

A.—A good mechanic will undoubtedly be able to shrink a roll of hardened tool steel on a shaft of machine steel without drawing the temper to an injurious extent. The pressure will tend to loosen the roll, but the roll may not become loose until the wear renders it unfit for use. We should, however, prefer to have the roll and shaft in one piece, even if these have to be made of tool steel.

946. Q.—What is the process of galvanizing?

A.—The process consists simply in covering sheet iron with a thin coating of zinc. To effect this result the iron plates are first immersed in a cleansing bath of equal parts of sulphuric or muriatic acid and water, used warm. They are then scrubbed with emery or sand to clean them thoroughly and detach all scales, if any are left; after which they are immersed in a preparing bath of equal parts of saturated solution of chloride of zinc and chloride of ammonium; from which bath they are directly transferred to the fluid metallic bath consisting of 20 chemical equivalents of zinc to 1 of mercury, or, by weight, 640 pounds of zinc to 106 of mercury, to which are added 5 to 6 ounces of sodium. As soon as the iron has attained the temperature of this hot fluid bath, which is only 680 degrees Fahr., it may be removed, and will then be found thoroughly coated with zinc. Care must be taken not to leave the plates too long immersed in this bath, as its affinity for iron is such that they may become dissolved. This is the case with thin plates of wrought iron, which, even when ⅛ inch thick, may be dissolved in a few seconds. It is safe, therefore, to let the bath previously act on some wrought iron, so that it dissolves a portion of it, in order to satisfy its inconveniently great affinity for this metal.

947. Q.—Please give me a method by which I can galvanize small castings so that solder can be made to adhere to them. They will weigh about ½ pound each.

A.—Cleanse the castings in an ordinary tumbler or rattler. When the sand is all removed take them out and heat one by one, plunging, while hot, into a liquid composed as follows: 10 pounds hydrochloric acid, and sufficient sheet zinc to make a saturated solution. In making this solution, when the evolution of gas has ceased, add muriate, or, preferably, sulphate of ammonia, 1 pound, and let it stand until dissolved. The castings should be so hot that, when dipped into this solution and instantly removed, they will immediately dry, leaving the surface crystalized, like frostwork on a window pane. Next, plunge them while hot, but perfectly dry, into a bath of melted zinc, previously skimming away the oxide on the surface, and throwing thereon a small amount of powdered sal-ammoniac. If the articles are very small, enclose them in a wrought-iron basket on a pole, and lower them into the metal. When this is done, shake off the superfluous metal, and cast into a vessel of water to prevent them from adhering when the zinc solidifies.

948. Q.—How are the figures and lines made on steel tapes?

A.—An examination of a steel tape shows beyond reasonable doubt that in that instance, at least, the figures and lines on the polished tape were covered with some substance—wax probably—and the rest of the surface treated with acid.

949. Q.—I have several hardened tools on which I wish to write my name. I have tried nitric acid, covering the surface with beeswax, but the result is not good. The lines are scratchy, and the metal outside is pitted. Can you tell me of a better way?

A.—Use a mixture of about six parts nitric to one of muriatic acid. Warm the steel and cover carefully with the wax or the acid will penetrate at the edges of the letters and pit the steel as you say. To get clear letters you must cut the wax away smoothly, otherwise the edges will be ragged.

950. Q.—What is the paint, or how is it made, to be used on hard steel when certain parts are to be taken off with nitric and muriatic acid? I have used beeswax, also asphaltum, without success.

A.—For etching on steel, the etching ground is composed

of equal parts of beeswax, Burgundy pitch and asphaltum; these are melted together and should be thoroughly incorporated. Warm the steel to a degree which will readily melt the wax by contact. Spread a small quantity of the etching ground evenly over the surface with a dabber or a ball of cotton covered with silk. When cold, remove the ground where the metal is to be etched and apply the etching fluid, which consists of nitric acid 1 part and water 4 to 6 parts. After the biting is done, which will take a few minutes only, dip in hot water and wash off the acid. After this the surface can be cleaned by wiping with benzine. Sometimes the following method is adopted: Make a varnish of asphalt and turpentine mixed with a few drops of linseed oil to make it tacky. Procure a rubber stamp on which the required design is depressed, and having a border around the design. Apply the varnish with the stamp in the same manner as in stamping goods, on border put a small rim of beeswax; then apply the acid within the border. After it has etched deep enough, which may take a few minutes only, pour off the acid, rinse the surface with clean water, take off the putty, and clean off the varnish with turpentine.

951. Q.—P. asks for the composition of an acid mixture for etching steel or iron articles and for instructions for using the same.

A.—The following composition is recommended for this purpose: Pyroligneous acid 4 ounces, alcohol 1 ounce, nitric acid 1 ounce, by measure. Before applying this fluid to the object to be etched it is important to have the iron or steel clean; after which the surface of the metal on which the etching is to be done should be evenly covered with a thin film of wax, the object of which is to protect that part of the surface not to be etched from the action of the mordant. The lines are then cut through the wax and the fluid poured on. As soon as the metal is sufficiently etched the fluid may be washed off.

952. Q.—What kind of acid can I use to eat tool steel? I want to use it to relieve the cutting dies of a pipe-threading machine.

A.—The threads should be thoroughly cleaned and the parts which are not to be touched by the acid should be protected by wax. This may be done by warming the dies sufficiently to melt the wax, and then pressing the points of the teeth into a cake of wax; or the teeth may be entirely covered by dipping

into melted wax, and the wax may then be scraped away from the surfaces to which the acid is to be applied. Use a mixture of equal parts nitric acid and muriatic acid, appplying with a feather, and when the steel is supposed to be sufficiently eaten, wash in water, which stops the process. It would be well to experiment with some unimportant piece of similar steel first.

953. Q.—Is there a solder with which we can mend small cast-iron (2-ounce) castings with a heat that will melt hard solder? We find that by using common solder the muriatic acid in a short time rusts under and lets the solder loose.

A.—Clean the surfaces of the fracture with a file, then take a piece of wrought iron, and clean it also by filing. Place the wrought iron in the fracture, wire the parts together and braze with spelter solder, using borax as a flux in the usual way. This process, if properly carried out, will secure a joint which will not rust, and will be so strong that the casting will be likely to break at some other place, rather than at the former fracture.

954. Q.—How shall I make a wiped joint such as is sometimes made on lead pipe?

A.—Melt the solder in a ladle and pour it on the joint quite plentifully, so as to heat it. As the solder accumulates wipe it into shape with a piece of cloth (bed ticking is good for the purpose), folded several times and greased with tallow. The cloth is also used to hold the solder as it is poured on the pipe.

955. Q.—Please name the kind of metal to use, and the manner of using it, for brazing steel.

A.—Sheet steel or thin pieces, such as band-saws, are generally brazed with silver solder, which is sold in strips. For brazing a band-saw, the ends are to be tapered off so as to form a common scarfed joint. The ends are to be securely held in position, leaving a space all about the joint. A piece of silver solder, wet with soldering fluid, is to be placed between the joint; then with a pair of blacksmith's tongs, previously heated to a white heat, grasp the joint. Sufficient heat will be transmitted to the steel to melt the solder and firmly unite the ends. The tongs should be held in contact with the saw until the solder has set, otherwise the parts will be imperfectly united.

956. Q.—How can I blacken brass work upon optical instruments so that it will bear handling without rubbing off?

A.—Make a strong solution of nitrate of silver in one vessel and nitrate of copper in another. Mix the two together and plunge in the brass. The brass after being removed from the bath should be heated evenly until the required degree of dead blackness is obtained. This method is of French origin and was kept a secret for years, being used for the ornamenting of optical and other scientific instruments.

957. Q.—What is a good method for drilling small holes in glass, in regard to style of drill and speed of machine and lubricant to be used; by small holes I mean ⅛-inch or smaller?

A.—Put a piece of brass tubing in the drill spindle, the outside of the tube being equal to the size of the hole you desire to make. Revolve rapidly, and feed with emery and water. For making holes in thin glass, put a piece of stiff clay or putty on the part where you wish to make the hole. Make a hole in the putty or clay equal in diameter to that of the hole you wish to make, letting the hole reach the glass, of course; into this hole pour a little molten lead, and the piece will drop out.

958. Q.—How is the elastic limit practically determined?

A.—By a testing machine having appliances for measuring both the loads applied and the elongations. Up to the elastic limit the elongations are proportional to the loads, but above that point the elongations increase faster than the loads, and the point where the change appears marks the elastic limit.

959. Q.—We expect to have to balance some separator bowls, such as are used in creameries, and which run at about eight thousand turns per minute, which would be a fine job of balancing. How is it best to do it?

A.—We happen to know quite intimately the practice followed in balancing the baskets of hydro extractors or centrifugal machines in one of the principal establishments devoted to their manufacture. The practice followed there is that of continually trying balancing pieces of different weights and in different positions, until the conditions are found which result in smooth running. After the size and position for the required balancing piece are determined, a piece is got out and riveted on in the place indicated. This would seem to be a rather crude practice, but is superior to the calculus for the purpose, and takes but a short time when a man is expert.

960. Q.—Is there any way that I can rig up so as to be able to see a wheel or anything that is revolving at considerable speed? For instance, how can I manage to watch the action of a flywheel governor? I have chalked the weights and when the wheel is running they make a white ring, and if the governor changes the ring gets bigger or smaller; but I don't get much satisfaction out of that, and I would like to be able to see the governor work just as if it was standing still.

A.—You can easily see your flywheel or any other revolving wheel at any speed "just as if it was standing still." It is to be supposed that your wheel has light enough upon it so that it can be seen clearly, and then if you contrive to revolve a looking-glass in such a position that you can see a reflection of the wheel every time the glass turns over, and if the glass revolves at the same speed as the wheel, you will see the wheel standing still. It is not even necessary to have a looking-glass. You can attach a flexible shaft or tube to the center of the engine shaft, and have it long enough so that you can turn it around anywhere while it is running, with some kind of a sleeve or bearing near the end of it that you can hold in your hand, and right on the end of it a disk sticking out edgewise. Have a hole near one edge of the disk, so that you will see the wheel that you want to look at through the hole once for every revolution; and no matter how fast the wheel goes around, it will look as though it were standing still and you should be able to watch the changes of the governor to your heart's content.

961. Q.—How are the coils (pipe) in the Baker car-heater made?

A.—The inventor and manufacturer of the heater in question, Mr. Baker, replies as follows: "There are various ways of winding or coiling pipes into spiral form. The primitive manner was to do it by successive heating and bending, by piecemeal, and in the blacksmith's fire and forge. They have also been coiled cold. This operation requires powerful machinery; but as the grain or fiber of the iron is simply distorted or disturbed instead of being welded, the coil soon, though gradually, loses its form and tends to return to a straight line. We make all of our various sizes and lengths, first cutting the pipes, usually 1¼-inch size, to the proper lengths; then evenly heat the same in a blast furnace of corresponding length. The entire length is

evenly made red-hot; then, by a hand-operated windlass within the furnace, the coil is quickly wound into the exact form desired, and in which form it always remains."

962. Q.—How is celluloid polished? Would it be transparent if it was cut with a milling machine?

A.—The Celluloid Company, New York, which controls the manufacture of that material, replies that "celluloid can be polished by the same methods that are used for hard rubber. A cloth buff wheel with fine emery powder, and then finish with rotten stone, is what we use." It is not likely that it would be very transparent after milling unless polished, though a simple test would quickly decide this.

963. Q.—How are cold saws tempered?

A.—They are hardened in the same way that saws for wood are hardened, the only difference being in drawing the temper, which for wood saws is brought down to a blue, while cold saws are sometimes left as they come out of the oil bath. Saws for wood are tempered in the following manner: The saw is first heated to a light cherry red, and then plunged into a bath composed of whale oil, tallow, rosin and beeswax, the proportions of which we could not learn. After taking the saw out of the bath, it is cleaned by scraping and scouring with sawdust. For drawing the temper the saw is placed between plates brought together by hydraulic pressure. The plates or dies are circular in form and horizontal in position and placed in furnace with an adjustable blast, and are revolved to keep the temperature even. There is danger that cold saws when taken out of the bath may be too brittle and may cause resious results when put in use. In such cases, of course, the temper must be drawn as described above.

964. Q.—Can you give simple instructions for making blueprint paper?

A.—The following proportions give as good results as any which we have seen: First solution, ½ ounce red prussiate of potash, 3¼ ounces water; second solution, ¾ ounce citrate of iron and ammonium, 3¼ ounces water. For the coating solution, mix in equal parts. Apply with a camel's-hair brush similar to those used with press copy books. Apply freely, but not so freely as to have the solution stand in puddles. The paper should dry hanging by its edge, in order to drain off

superfluous solution, and should be so far as possible non-absorbent. The chemicals should be bought in original packages to insure their being fresh, and the citrate should be kept in a tin box, or otherwise in absolute darkness. Especially and particularly absolute cleanliness must be observed. A brush on which the solution has been allowed to dry exposed to the sun is ruined for all time. Immediately after use, the brush should be rinsed repeatedly, until there is no show of solution in the water.

965. Q.—I want to know how to cast the lower die, made of soft metal, used in the common seal press.

A.—The metal, often type metal, is heated and poured in a plain cast-iron form or box not much larger than the required size of the die, the metal is allowed to cool, and just when it is about to solidify, the upper die, fastened to the under side of a weight, is allowed to drop on the metal. The hight through which the upper die must drop and the amount of weight upon it can only be determined by experience. In dropping, the die and weight must be guided by suitable means. Sometimes, in place of dropping, pressure is applied so as to obtain a good, clear impression.

966. Q.—What is the cheapest and best way of reducing a malleable metallic alloy to a powder of about the consistency of drillings from cast iron? The alloy has somewhat the physical properties of zinc.

A.—The process by which tin is granulated might work with your alloy, and we advise you to try it. A suitable quantity of tin is thoroughly melted in an iron ladle deep enough to give liberty for the subsequent operation. When the tin is completely melted the pot or ladle is removed from the fire and allowed to cool. As the metal begins to solidify, or a little before that, it is stirred briskly and constantly with the result that the metal is finally left in minute particles. Sometimes the partly solidified metal is thrown into a strong cloth, quickly wrapped up like a pudding in a bag, and pounded all over with a stick or mallet. The tin after it is thoroughly cooled is sifted through a sieve of the desired fineness, and what is too large may be remelted and the granulating process repeated. Metals are sometimes granulated by melting and pouring through a broom into water.

967. Q.—What is the process and composition of the rubber used by dentists in the manufacture of artificial teeth?

A.—Mr. John T. Usher, of this city, gives us the following information: "The formulas for the rubbers generally used for artificial dentures are as follows:

Red Rubber:

Caoutchouc (rubber gum)	48 parts
Sulphur	24 "
Vermillion (red precipitate or oxide of mercury)	36 "
Total	108 parts

Black Rubber:

Caoutchouc	48 parts
Sulphur	24 "
Calcined bone or lampblack	36 "
Total	108 parts

Pink Rubber:

Caoutchouc	48 parts
Sulphur	24 "
Zinc oxide	30 "
Vermillion	10 "
Total	112 parts

The above rubbers are what are termed the fifty-five-minute rubbers, which means that they are to be vulcanized for fifty-five minutes at a temperature of 320 degrees Fahr. There are, however, a great variety of other formulas by which dental rubbers are compounded, the proportions of which are dependent, first, on the temperature and time at and in which the rubber has to be vulcanized; second, the color the vulcanized product is to be; third, the quality and price of the unvulcanized rubber. In all dental rubber the vulcanizing agent employed is sulphur, and the proportions for the fifty-five-minute rubbers are 2 parts caoutchouc (koo-chook) to 1 part sulphur, the other ingredients being added for the purpose of coloring and adulterating. For the quicker vulcanizing rubbers a larger proportion of sulphur is added to the caoutchouc, and for the slower vulcanizing rub-

bers a less proportion of sulphur, which latter also applies to the soft rubbers, such as employed in making 'soft centers' in artificial dentures for soft palates."

968. Q.—How is the mandrel made for winding the wire handles that are now used on stove lifters, tea kettles and such things? How is the mandrel got out, or how is the coiled wire got off the mandrel?

A.—No mandrel is used for the purpose. The wire handles with the swell in the middle, the quick taper at one end and the longer taper at the other, are rolled out continuously from the coil of wire and are cut off at the proper intervals that apportion the complete shape to each. A little doctoring of he mutilated end is all that is required to complete the job. The coil of wire is mounted upon a reel, and the first end of it is led through a straightening apparatus, and it then passes between three or four more pairs of rollers, all gripping it tightly and all helping to push it along for the bending or coiling operation, which requires considerable power. As the wire emerges from the last pair of rollers, the side of it comes in contact with the periphery of a wheel or cam of peculiar shape, which causes the wire to curve as it emerges and assume the shape desired. This shaping wheel is free to move upon its own axis, and one revolution of the wheel is coincident with the production of the complete handle. The principle of operation is perfectly simple. As the wire comes out from the driving rolls a true, circular, freely revolving wheel, placed in the same plane as the driving rollers, but so that its periphery overlapped the path of the emerging wire, would bend the wire to the side, and it would form a circular ring. This operation could not be continued, because the end of the wire would soon come in contact with the emerging wire; but if this wheel, still perfectly circular, were pitched so that while it bent the wire around it would also pitch it forward, the wire would then form a helical or "spiral" spring, and springs of any length or pitch or diameter may be quickly made in this way. Now if the wheel thus adjusted, instead of being perfectly circular, should vary from the true circle, so that the radius at one point was greater or less than at a preceding point, that would change the diameter of the spring that was being coiled. Where the radius of the wheel grew less, it would

crowd the wire less, and the diameter of the coil would be larger; where the radius grew greater, the wheel would crowd the wire more and then it would coil smaller. This wheel, it will be seen, can only be satisfactorily made and adjusted by experiment, and often by tedious and protracted experiment; yet there are plenty of men in these days who would not hesitate to ask for a formula for it.

969. Q.—Which is the best method of making rust joints? I have over 1,000 feet of 3-inch boiler tubes to put overhead in our factory. I have never made any rust joints; kindly inform me what to use and how to use it as packing around flanges.

A.—If rust joints are to be used for the above boiler tubes, we pity the man that has the job. Rust points are usually made with sifted cast-iron turnings, sal-ammoniac and a little sulphur mixed to a rather stiff paste with water and packed into the joint with a chisel or calking iron. One part sal-ammoniac, 2 flowers of sulphur and 80 of iron turnings, by weight, is given for quick setting and 1 sal-ammoniac, ½ sulphur and 100 of iron for slow setting. It is better to omit the sulphur entirely.

970. Q.—In copper plating small steel articles, I dip them in a solution of 1 part of blue vitriol dissolved in 3 parts of rain water, but the copper rubs off very easily. How should it be done so that the copper will stay on?

A.—The articles must first be well cleaned, and then painted over with a solution of protochloride of tin, and immediately afterward with an ammoniacal solution of sulphate of copper. The layer of cooper thus produced adheres so firmly to the iron or steel that the different objects can be rubbed and polished with fine chalk without injuring the deposit. The tin solution is prepared with 1 part crystallized chloride of tin, 2 parts water, and 2 parts hydrochloric acid. The copper solution is prepared with 1 part sulphate of copper, 16 parts water, adding ammonia sufficient to precipitate and redissolve.

971. Q.—Where can I buy diamond drills? How are they made and what are they used for?

A.—The diamond drill is principally used for boring in rock, either in prospecting for mineral deposits or for foundations of important buildings and similar engineering work. The drill proper is a steel tube upon the lower edge of which are mounted several

diamonds which do the cutting, some of the diamonds slightly overhanging the outside and the alternate ones cutting for the inner edge of the tube to clear. The drill is revolved at consider able velocity, and a stream of water is constantly fed to it to wash away the cuttings, which are usually dust. As the drill is fed forward a central core is left which can be removed in long sections as reliable specimens of the strata penetrated. The drill tube is successively spliced and penetrates to depths of several hundred feet. For simple drilling the regular rock drill is cheaper and quicker in operation. In accordance with the general American practice, the term "drill" also applies to the entire apparatus.

972. Q.—Please furnish me with a formula for making a solution for oxidizing brass to a good black color by simple immersion. It will have to work quickly, and not be too expensive. The work will have to be handled some before it can be lacquered, so that it will be necessary that it do-s not rub off easily.

A.—The following solution is recommended for obtaining a deep black color on brass: Dissolve 100 parts of copper nitrate in 100 parts of water. If the article is large, then paint it with this solution; if small, immerse it in the solution. After draining off or shaking off the excess of the solution, heat the article until the copper salt is decomposed into a black copper oxide. The work may be heated over a clear coal fire, but better results may be obtained by heating the articles in a closed muffle furnace. For some kind of work you may obtain more uniform results by using a weaker solution than given above, namely, 100 parts of copper nitrate to 300 parts of water.

973. Q.—What is meant by sub-press work? What is the difference between a sub-press and the ordinary power press?

A.—A sub-press is simply a small frame with a base-plate and upright; the base-plate adapted to hold a die, and the upright fitted with a plunger adapted to carry the punch. In this frame the die and punch are permanently adjusted in their proper relation to each other, and the plunger is then given its motion by the slide of the regular punch press, the sub-press being placed upon the bolster of the punch press. When jobs are changed upon the machine the entire sub-press is removed without disturbing the adjustment of the die and punch, and the

arrangement enables much finer and closer punching work to be done than is usually possible by the ordinary methods. In fact, practically all the finer class of punching is done by the use of a sub-press.

974. Q.—How is black lacquer for brass and steel made and applied?

A.—The process of lacquering or japanning, frequently adopted in machine shops, is to give the articles, made of brass, steel or iron, a coat of black japan varnish, made specially for the purpose, and then placing the articles in an oven and allowing them to dry in a temperature of 250 to 300 degrees Fahr., or higher. By this process the articles will have a uniform glossy surface, which is retained on cooling. Metals can also be given a lustrous black as follows: The bottom of a cylindrical pot, which should be about 18 inches in hight, is covered ½ inch with powdered bituminous coal; a grate is then put in and the pot filled with the articles to be varnished. Articles of cast iron, iron wire, brass, zinc, steel, etc., may be subjected to the same treatment. The cover is then put on and the pot heated over a coke fire under a well-drawing chimney. In the beginning the moisture only evaporates, but soon the cooking commences and deep brown vapors escape, which irritate the throat. When the bottom of the pot has been heated for fifteen minutes to a dull red heat the coal has been mostly converted into coke. The pot is then removed from the fire, and after standing for ten minutes, opened for examination. All the articles will then be covered with a thin lustrous coating which cannot be easily scratched. This lacquer is not only a protection against oxidation of metals, but will stand also a considerable heat, only disappearing at beginning of redness.

975. Q.—How can I mold small articles in rubber, which, after molding, must be soft like sheet rubber? Please tell me where I can obtain a small vulcanizer, and its cost. Are there any books treating on molding rubber?

A.—Mr. John T. Usher replies as follows: "The molds for soft rubber are the same as for hard rubber, and any article can be made either of hard or soft rubber in the same mold; but when the articles are made of soft rubber, no provision need be made in the molds for removing the articles (after they have been vulcanized) from the molds, as in the case of hard rubber

when metal molds are used; for when the articles are made of soft rubber they can easily be pulled out of the mold, if the latter is correctly made. Your correspondent should experience no difficulty in making a metal mold without any special appliances, except some molding sand, a ladle and some white metal or good babbitt metal; or if he wants to make the articles in plaster molds, he should make them right in the flasks. With regard to the soft rubber, of which mention is made, your correspondent is very indefinite on this point, though I presume he refers to the kind of rubber of which hand stamps are made. If he does, then this kind of rubber can usually be vulcanized in the steam vulcanizer in practically the time taken to raise the temperature to the vulcanizing point, and then cooling off slowly, holding the temperature at the vulcanizing point for about five minutes, and then shutting off the heat. The object in holding the temperature at the vulcanizing point for five minutes is to allow of the heat peretrating to the interior of the molds. It is possible that the above mentioned rubber may not be suitable for your correspondent's purpose. I should think the best rubber for his purpose would be the flexible rubber used by dentists when it is necessary to make a soft palate in an artificial denture. If the latter rubber is used, it is vulcanized the same as the hard rubber (though it never gets hard). With regard to former (hand stamp) rubber, this can be vulcanized by improvised methods; but, it is always best to use a vulcanizer. It is more than probable, though, that your correspondent may have to have his rubber made to order, if he is desirous of having any particular color and amount of elasticity in the rubber, in which case the rubber can be made to be vulcanized in any time desired. The most popular vulcanizer in use is the 'Whitney,' as made by the Buffalo Dental Manufacturing Company, Buffalo, N. Y."

976. Q.—What is the method usually adopted, and what material is used for japanning sheet iron or steel cheaply, after the manner of that used for corset steels and other work of a similar character? If used in the shape of dipping liquid or heated in an oven, what is the best temperature at which to work?

A.—Japanning is done in clear transparent varnishes, in black and in body colors; but black japan is the most characteristic

and common style of work. The varnish for black japan consists essentially of pure natural asphaltum, with a proportion of gum anime dissolved in linseed oil and thinned with turpentine; but there are numerous receipts given for the varnish, and manufacturers generally conceal the composition of their own preparations. In thin layers such a japan has a rich dark-brown color, and only shows a brilliant black in thicker coatings. For fine work, which has to be smoothed and polished, several coats of black are applied in succession, each being separately dried in the stove at a heat which may rise to near 300 degrees Fahr. Body colors consist of a basis of transparent varnish mixed with special mineral paints of the desired colors or with bronze powders. The transparent varnish used by japanners is a copal varnish which contains less drying oil and more turpentine than is contained in ordinary painter's oil varnish.

977. Q.—What is the quickest and cheapest method to tin railroad-car brasses so that they can take the lead lining?

A.—The bearings are first bored, they are then placed on a coke fire and allowed to become well heated, then they are cleaned with muriatic acid and tinned. They must be warmed again, so that the tin will be in a condition for the lead to adhere to it. They are then placed on a mandrel to receive the lining of lead. The device for holding the bearing during the lining can be of very simple construction. It should be so designed that the bearing can be clamped only central with the mandrel, which will make the lining of uniform thickness over the bearing. The radius of the mandrel should be 1-32 to 1-16 of an inch greater than the radius of the journal which the bearing is to fit. The lead lining should not be more than 1-16 of an inch thick.

978. Q.—What is the process of sweating brasses together as practiced in some shops? What is the mixture used, and how is it done?

A.—The surfaces of the castings which are to be united are first scraped or filed; they are then tinned or covered with solder. After this, the surfaces are placed against each other, and the castings are heated until the tin or solder melts; the surfaces are then pressed together, and thereby become united. The

pressure, sufficient to hold the pieces together, must be maintained until the tin sets.

979. Q.—B. wishes to know how to etch copper dials from a negative or tracing.

A.—Make a solution composed of fish glue, 2 ounces; water, 2 ounces; whites of two eggs; bichromate of potash, 80 grains. Let the solution stand for about an hour, and then filter through cotton, when it is ready for use. Float the plate twice with the solution and dry it over a small gas stove. After cooling, expose to the sun under the negative for one or two minutes, and then wash under the water tap for about two minutes. Burn it over a gas stove till it becomes a dirty brown color, and then etch with chloride of iron.

980. Q.—What is die sinking?

A.—It is the art of engraving and cutting dies for stamping coins, medals, etc., for forging and for all purposes of shaping material to a given form by pressure. The art includes the processes of planing, turning, drilling, chipping, filing and hardening.

981. Q.—What process is employed for making cold-rolled shafting?

A.—In cold rolling the previously pickled bar is passed in a cold state repeatedly between highly polished chilled cast-iron rollers, the reduction being controlled by frequent calipering. The general disposition of the roll-train is the same as for hot rolling, but permits unusually accurate adjustment of the rolls. Round bars are rolled over and over in the same groove, and rotated slightly between passes, for, of course, only a short arc at the top and bottom of the groove can conform accurately to the section aimed at. Thus, at one mill round bars receive on an average from 30 to 40 passes each, with a total reduction in diameter of about 1-32 inch when less than 3 inches in diameter, and about 1-16 inch when larger.

982. Q.—How is enameling done?

A.—Enamel is a vitreous substance or glass, opaque or transparent, and variously colored, applied as a coating on a surface of metal or of porcelain for purposes of decoration. It consists of easily fusible salts, such as the silicates and borates of sodium, potassium, lead, etc., to which various earths and metallic oxides are added to give the desired colors. These enamels are now

prepared in the form of sticks, like sealing wax, and for use are pulverized and applied to the surface either dry or moistened to form a paste. The object to be enameled is then exposed to a moderate temperature in a muffle, and the vitreous substance becomes sufficiently fluid to form a brilliant and adhesive coating. The exact temperature to which the object is to be exposed depends on the class of work to be enameled. These are various operations of enameling, and they require skillful manipulations, a knowledge of which can only be obtained by long practice.

983. Q.—What process is employed for browning shot-gun barrels?

A.—A variety of colors on iron and steel can be produced by means of a mixture of lead acetate and sodium thiosulphate. The following proportions may be used, with the results enumerated below, the colors altering with the time of immersion: Lead acetate, 50 grains; sodium thiosulphate, 50 grains; water, 5 fluid ounces. The solution must be used hot. 1, light brown color; 2, darker brown color; 3, purple and blue mixed; 4, purple and blue paler tone; 5, uniform light blue color; 6, steel gray; 7, black color, after half an hour's immersion. In order to produce a uniform color all over, the article must be completely immersed, so as to be equally heated. Another way is to dissolve in 4 parts of water, 2 parts crystallized chloride of iron, 2 parts chloride of antimony and 1 part gallic acid, and apply the solution with a sponge or cloth to the article, and dry it in air. Repeat this any number of times, according to the depth of color required. Wash with water, and dry, and finally rub the articles over with boiled linseed oil. The metal thus receives a brown tint and resists moisture. The chloride of antimony should be as little acid as possible.

984. Q.—Please inform me how to obtain a good black color on brass, for instance, such as found on surveying instruments.

A.—The following solution is recommended for obtaining a deep black color on copper and its alloys: Copper nitrate, 100 parts; water, 300 parts. The article, if large, is painted with it; if small, the article may be immersed in the solution. It is then heated over a clear coal fire and lightly rubbed. The article is next placed in or painted with a solution of the following composition: Potassium sulphide, 10 parts; water, 100 parts; hydrochloric acid, 5 parts. This composition need not be used in all

cases. Small work can be much more conveniently treated by immersion in the solution first given, and after straining off or shaking off the excess of the solution, to heat the work on a hot plate until the copper salt is decomposed into a black copper oxide. It would be difficult to heat large articles upon a hot plate; a closed muffle furnace should give better results than an open fire. In any case the heating process should not be continued longer than is necessary to produce the change mentioned above.

985. Q.—What liquid, not inflammable, will remove oil and grease from brass?

A.—Use a solution of potash or concentrated lye.

986. Q.—What is the liquid preparation used for writing on glass, the writing appearing as if engraved?

A.—It is said that a solution of fluoride of ammonium may be used with a quill pen, or you can cover the glass with wax, trace through and eat with fluoric acid.

987. Q.—Please give me a receipt for making a metal that will expand instead of contracting when cooling; to be used in filling small holes in castings, etc.?

A.—Lead, 9; antimony, 2; bismuth, 1 part.

988. Q.—Can you tell me of some way of cleaning the windows of a machine shop which have not been cleaned for some years and are covered with iron rust? I have tried several ways, but it takes too long.

A.—Use a solution of oxalic acid, instead of clear water.

989. Q.—Is there a glue of some kind which will fasten gutta percha and brass together?

A.—The following will be found serviceable for such purpose: Powdered shellac is softened in 10 times its weight of strong water of ammonia, giving a transparent mass, which becomes fluid after keeping for a short time without the use of hot water. In three or four weeks the mixture is perfectly liquid, and when applied will soften gutta percha. When the ammonia evaporates the gutta percha hardens again.

990. Q.—What acid will turn brass black so that it will be of a glossy nature?

A.—A black lacquer for brass is made of 1 part nitrate of tin to 2 parts chloride of gold. The article to be lacquered

should be finely polished, then washed with this mixture. After 10 or 15 minutes, wipe off clean.

991. Q.—Is there a solution for darkening sheet copper, and what is it composed of?

A.—Copper may be darkened by washing its surface with sulphuretted alkali (sulphuret of ammonia). The solution should be dilute, and after its application the metal should be dried at a gentle heat, and may then be polished with a hard hair brush; or dissolve 5 drachms nitrate of iron in 1 pint of water, and immerse the copper, or 5 drachms perchloride of iron in 1 pint of water will answer the same purpose.

992. Q.—How is liquid glue made?

A.—Put broken glue of the best quality in a glass jar, and pour in enough acetic acid to cover it. Set the jar in a kettle of hot water till the glue is melted.

993. Q.—What is a good solution walnut stain?

A.—To 1 quart of water add 1½ ounces washing soda, 2½ ounces vandyke brown, and ¼ ounce bichromate of potassa. Boil for 10 minutes and apply with a brush.

994. Q.—What is a good waterproof glue for holding walrus leather or felt to a wooden polishing wheel? By the use of common glue the water, in washing off a wheel, gets between the wheel and the covering, blistering the latter so that it is necessary to true the wheel up before covering with emery, which shortens its life more than all the work it has to do.

A.—You might try the following: Mix a handful of quicklime with 4 ounces of linseed oil; thoroughly lixiviate the mixture. Boil until quite thick and spread on tin plates. It will become very hard, but can be dissolved over a fire like common glue. Glue may be rendered insoluble by tannic acid dissolved in a small quantity of soft water.

995. Q.—How can I get an oil, suitable for guns and sewing machines, that will not gum?

A.—Take good Florence olive oil and put it in a bottle with some strips of zinc and shavings of lead, which should be clean. Expose the bottle to sunlight until the curdy matter ceases to be deposited. This will require considerable time, but the oil, when decanted, will be of very fine quality, and will not gum. A mixture of sperm oil and paraffine oil will also be found to be very good in this respect.

996. Q.—What is the mixture generally used on finished steel to give it a copper color, so that a design may be marked thereon?

A.—Dissolve bluestone in water and apply it to the steel, or take a piece of the bluestone (which can be obtained at any drug store), wet it in water, and rub it over the steel.

997. Q.—We have a stand-pipe, 12 feet diameter and 110 feet high, into which the water is pumped to supply the city. This stand needs painting. What should we paint it with? Should we paint it inside and outside?

A.—A good paint for preserving iron exposed to the weather appears to be pulverized oxides of iron, such as yellow and red iron ochres, or brown hematite iron ores finely ground, and simply mixed with linseed oil, and a dryer. Dixon's silica graphite paint will also give good results. We should paint the inside and outside of the pipe.

998. Q.—What is the best glue, cement or composition to make emery cloth adhere to polishing plates made of cast iron?

A.—Many things are suggested for this purpose, but, unfortunately, we are not so situated as to be able to say from experience which is the best. Paint the cast iron with white lead, and when it is dry and hard use best Russian glue dissolved in water with a little vinegar or acetic acid.

999. Q.—What soldering fluid will not rust iron or steel when applied to the same?

A.—It is said that a teaspoonful of chloride of zinc in two ounces of alcohol will make a soldering fluid that will not tarnish or rust the work.

1,000. Q.—Is there a solution in which I can dip polished tools to keep them from rusting?

A.—The best thing we know is to coat them with vaseline.

1,001. Q.—Which is the best and quickest way of cleaning paint and varnish brushes, especially those used in shellac varnish?

A.—Paint brushes which have become hard can be cleaned by soaking them 24 hours in raw linseed oil, and then rinsing them out in hot turpentine. Repeat this process till the brushes are clean. They may also be cleaned by washing them in hot soda and water and soft soap. Brushes used in shellac varnish can be cleaned by soaking them in alcohol.

1,002. Q.—What is a good lacquer to be used on brass castings after they have been finished?

A.—A lacquer for dipped work may be made thus: Alcohol, 12 gallons; seed lac, 9 pounds; turmeric, 1 pound to the gallon; Spanish saffron, 4 ounces. The latter may be omitted if the lacquer is to be very light.

1,003. Q.—How is the ormolu dip made, such as is used for brass work?

A.—The ormolu dipping acid is a mixture of niter, 6 pounds; sulphuric acid, 1 gallon; nitric acid, ½ pint; muriatic acid, ½ pint. The muriatic acid should be put in last, a little at a time, and the mixture stirred with a stick.

1,004. Q.—What cement can be successfully used for rubber and leather belts to be subjected to moisture and hard usage, for instance, for portable saw mills, farm engines, etc.?

A.—For leather belts, take of common glue and American isinglass equal parts; place them in a glue pot and add water sufficient to cover the whole. Let it soak 10 hours, then bring the whole to a boiling heat, and add pure tannin until the whole appears like the white of an egg. Apply warm. Buff the grain of the leather where it is to be cemented, rub the joint surfaces solidly together, let it dry for a few hours, and the belt will be ready for use. For rubber belts take, 16 parts gutta percha, 4 parts india rubber, 2 parts common caulker's pitch, 1 part linseed oil; melt together and use hot. This cement can also be used for leather.

1,005. Q.—What is the best substance for filling the sunken letters of brass checks—something easily applied, and still durable?

A.—We do not know of anything better than asphaltum. This can be melted, the cavities filled, and then the surface polished.

1,006. Q.—Can you tell me the composition of a paste not likely to be affected by acids?

A.—Melt together 1 pound resin, 3 ounces beeswax and 4 ounces red ochre, dried and warm. Add 1 ounce plaster of Paris, heating the whole to about the heat of boiling water.

1,007. Q.—What is the process of silvering iron?

A.—The iron is first covered with mercury and silvered by the galvanic process. By heating to 570 degrees Fahr. the mercury evaporates and the silver layer is fixed. Iron-ware is first heated with dilute hydrochloric acid and then dipped into a solution of mercury nitrate, being at the same time in communica-

tion with the zinc pole of an electric battery, a piece of gas carbon or platinum being used as an anode for the other pole. The metal is soon covered with a layer of quicksilver and is then taken out and well washed and silvered in a silver solution. To save silver the ware can be first covered with a layer of tin; 1 part of cream of tartar is dissolved in 8 of boiling water, and one or more tin anodes are joined with the carbon pole of a Bunsen element. The zinc pole communicates with a well-cleaned piece of copper and the battery is made to act till enough tin is deposited on the copper, when this is taken out and the ironware is put into its place. The ware thus covered with tin chemically pure and silvered is much cheaper than any other silvered metals.

1008. Q.—Can you give me the coloring matter used in lacquer for both red and yellow brass?

A.—You can get any desired color by making your lacquer as follows: Put 4 ounces best gum gamboge into 32 ounces spirits turpentine; also put 4 ounces dragon's blood into the same quantity spirits turpentine, and 1 ounce annallo into 8 ounces spirits turpentine. These three mixtures are to be made in different vessels. They should be kept exposed to the sun for three weeks, when they are ready for use. Any desired color may be had by mixing these solutions to produce it.

1,009. Q.—What mixture is used for dipping brass to prevent tarnishing?

A.—Alcohol, 12 gallons; seed-lac, 9 pounds; turmeric, 1 pound to the gallon; Spanish saffron, 4 ounces to the gallon.

1,010. Q.—What alloy will melt at 160 degrees temperature?

A.—It is said that an alloy of 3 volumes (not parts by weight) of cadmium, with 4 each of tin, lead and bismuth, will melt at a little less than 160 degrees.

1,011. Q.—We have barrels of water placed around our buildings to be used in case of fire. What is the best material to put in the water to keep it from freezing, and what effect will it have on the fire?

A.—Common salt is the best material, to our knowledge, for this purpose, and it will materially aid in extinguishing the fire. By using coarse "agricultural" salt the expense will be very much reduced.

1,012. Q.—What is a good paste to stick labels upon smooth, clean castings for shipping purposes?

A.—A cheap shellac varnish will answer the purpose very well. Apply to the casting with a brush, then lay on the label and rub down with the same brush. By so doing a coat of shellac is applied to the surface of the label, making a waterproof covering which effectually protects it from rain.

1,013. Q.—What is a good cement for leather that will stand moisture; also for rubber?

A.—A cement for leather that is said to be waterproof is made by dissolving gutta percha in bisulphide of carbon until it is about as thick as molasses. The parts to be united are covered with this and placed under pressure until united. A cement recommended for rubber is made by melting together 16 parts gutta percha, 14 parts india rubber, 2 parts caulkers' pitch, and 1 part linseed oil. To be used hot.

1,014. Q.—I want a receipt for a good iron paint, one that will be very hard, and which will not crack and peel off.

A.—Well-boiled linseed oil, to which is added a suitable coloring matter, is recommended. If a dark color is required, burnt umber is preferable to any other pigment as a stain; it is a good hard dryer, and has many other good properties and mixes well with the oil without injuring it. The iron should be first well cleaned and freed from all rust and dirt; the oil should be of the best quality and well boiled, without litharge or any dryer being added. After it has been boiled, add the coloring matter. The iron should be painted over with this, but should be laid on as bare as possible, as on this fact depends, in a great measure, the success of the application; for if there be too thick a coat of oil put upon the work, it will skin over, be liable to blister and scarcely ever get hard. But if the iron be painted with three coats of oil, and only so much put on each coat as can be made to cover it by hard brushing, it is claimed that the same will preserve the iron from the atmosphere for a much longer time than any other process of painting. There are other good and suitable paints, which can be obtained from any first-class dealer in paints, when he knows for what purpose the paint is to be used.

1 015. Q.—What chemicals are used with an alloy of copper, tin and antimony, generally called babbitt metal, to cause it to flow freely?

A.—There are no chemicals used for this purpose. Your trouble is probably due to chilling the metal in pouring. The bearing, or whatever the babbitt metal comes in contact with, should be kept warm. Sometimes a little oil put on top of the metal before pouring will have a beneficial effect. Of course care should be taken that the metal is not so hot as to cause the oil to ignite.

1,016. Q.—What solution can I use to prevent rust on articles made of steel wire? I cannot use vaseline or paint, nor "Manocitin," nor anything of the sort, but would like to get hold of something that I can use in solution and dip the pieces.

A.—Perhaps lime-water will answer. Articles of iron or steel submerged in water in which lime has been dissolved do not rust, and when taken from the water and allowed to dry, the thin coating of lime over them prevents rusting; but it is, of course, easily brushed off by handling.

1,017. Q.—Can you tell me how rust stains can be got out of my "biled" shirts?

A.—Dissolve a level teaspoonful of oxalic acid in half a tumbler of water, and wet the spots with the solution, renewing the application until the spots disappear, and then rinse in clear water. Finally, sponge with dilute ammonia—a teaspoonful of "household" ammonia to half a tumbler of water—and allow it to dry. The oxalic acid is poison.

1,018. Q.—Can you give me a recipe for a glue that will hold a strip of felt to a piece of tin or any other bright metal? It must be waterproof and easily applicable.

A.—Try shellac dissolved in wood naphtha. Apply cold.

1,019. Q.—Can you give me a good receipt for mixing the cements used in concrete sidewalk lights; also one to cement the ordinary bull's-eye glass for the same purpose?

A.—A mixture of tar and sulphur of the consistency of putty is often used for the purpose. Another cement is made of soluble glass thoroughly stirred and mixed with fine chalk, and the coloring matter well incorporated. As soluble glass can be kept on hand in liquid form, and the chalk and coloring matter are permanent and cheap, the colored cements can be readily prepared when wanted, and the material can be kept in stock ready for use at but little expense. If a black color is required, use for the coloring matter well-sifted sulphide of antimony.

Another kind of cement is made of litharge and red lead, equal parts, mixed thoroughly and made into paste with concentrated glycerine to the consistency of soft putty. This cement takes some little time to dry, but turns almost as hard as stone, and is fireproof and waterproof. Any of these cements you may use for the purpose mentioned.

1,020. Q.—What is the composition of Parsons' white brass used in bearings for large marine engines?

A.—The composition of No. 2 quality is: Tin, 68; zinc, 30.5; copper, 1, and lead, 0.5. It is used for facing and lining bearings.

1,021. Q.—What will securely fasten paper to a polished metal surface?

A.—Dissolve rye flour in a solution of caustic soda, dilute with water, and in so doing stir well all the time. To this paste add Venetian turpentine, a few drops for each ½ pound of flour. This paste will adhere firmly to glass, tinfoil and all metals.

1,022. Q.—Can you give me a formula for making a hekograph pad for duplicating mechanical drawings, a pad from which the impression can be easily washed or removed when a sufficient number of copies have been taken?

A.—There are several recipes both for the pad and the ink, none of which we can guarantee as best. Soak an ounce of gelatine overnight in enough cold water to cover it well, taking care that all the gelatine is swelled. Dissolve 2 ounces of salt in a pint of water for a bath. Heat 6 or 7 ounces of pure glycerine over the salt-water bath to a temperature of 200 degrees Fahr. Pour off from the gelatine all the water remaining unabsorbed, and add the gelatine to the hot glycerine. Continue the heating for an hour, carefully stirring the mixture occasionally, avoiding as much as possible the formation of bubbles or froth. Add 20 drops of oil of cloves to prevent decomposition. The composition is to be poured into a flat vessel of sufficient area, and allowed to stand level until cool. To prepare the pad for copying, it is necessary to pass a wet sponge lightly over the face and allow it to nearly dry before taking the first copy. After taking the desired number of copies, or when the impression is exhausted, the pad is to be washed lightly with a sponge wet in cold water, and allowed to dry before using again. For ink, use a strong aqueous solution of aniline black, in the proportion of about 1 of the coloring material to 5 or 7 of water. It should be a saturated solution and rather thick.

1,023. Q.—Give me a receipt for lacquering brass work.

A.—Lacquers have various ingredients, according to the depths and shades of color required. The following is for a gold lacquer for brass: Mix ½ pound seed-lac, picked clean, and clear of all pieces, with ½ pint rectified spirits of wine; keep them in a warm place, and shake them repeatedly. When the seed-lac is quite dissolved, it is fit for use. If the brass work is old, clean it first in the following manner: Make a strong lye of wood ashes, which may be strengthened by soap lees; put in the brass work, and the lacquer will soon come off; then have ready a mixture of aquafortis and water, sufficiently strong to take off the dirt; wash it afterwards in clean water, and lacquer it with the above mixture. If the brass work is new, it merely requires to be free from dust, and rubbed with a piece of wash leather, to make it as bright as possible. Put the work on a hot iron plate (or upon the top of a stove) till it is moderately heated, but not too hot, or it will blister the lacquer; then make the above mixture warm, lay hold of the work with a pair of pincers or pliers, and with a soft brush apply the lacquer. Care must be taken not to rub it on, but stroke the brush gently one way, and place the work on the hot plate again till the varnish is hard; but the work should not remain on plate too long. Experience will indicate when it should be removed. Some, indeed, do not place it on the stove or plate a second time. If it should not be quite covered, repeat the lacquering carefully. If pains be taken with the lacquer, the work will look like metal gilt.

1,024. Q.—I am about to manufacture dampers out of sheet steel or iron. I would like to know what I can use to stain or color them black that will be cheap and can be used as a dip without leaving much drip, something that will also prevent them from rusting.

A.—The following solution for producing a dark color on iron and steel has been recommended: Ferric chloride, 10 parts; water, 200 parts; potassium sulphide, 1 part. The articles may be immersed in the solution or painted with it, then allowed to dry by exposure to the air, and finally brushed with a waxed brush. A fairly good black bronze may be obtained in this way. This solution, with the omission of the potassium sulphide, may

be used for bronzing iron or steel. The color is brown after two immersions, with subsequent air drying, and uniformly distributed over the surface. A dense and fairly uniform grayish-black color can be produced on iron by digesting flowers of sulphur with turpentine, painting the work with the liquid, allowing to dry, and then heating over a clear fire or on a hot stove. The foregoing has been taken from "Metal Coloring and Bronzing," by A. H. Hiorns.

Miscellaneous.

1,025. Q.—Can I learn the elements of the machinist trade in a reaper and mower shop?

A.—Yes.

1,026. Q.—I am seventeen years of age and intend some day to be a mechanical engineer. I am now in second year of the high school. What would be the best thing for me to do, stop school now and go for a few years in a machine shop or drafting office and then go to a technical school, and get my practical education afterward?

A.—Do not leave the high school; get all the education you can. As to whether first to enter the machine shop or technical school you must use your own judgment, and be guided by the advice of your teachers and friends who are better acquainted with you and your abilities than we are.

1,027. Q.—I am an apprentice learning the trade of a machinist. I have worked two years in a rather rough shop, and sometimes I work a month at a time on sheet-iron work, but I have run a lathe and planer probably one-half of the time. What I want to ask is, if it would not be better to leave and go to some other shop to finish my trade?

A.—As we understand it, you have agreed to work a certain time to learn a trade, and taking your own statement we fail to see that you have serious cause for complaint. One year of the first two in a machine shop at the lathe and planer seems to us to be very good indeed. The knowledge you have, or can gain, of sheet-iron work will always be an advantage to you. We advise you to do exactly as you have agreed to do, and the fact that you always do this will be one of the best possible recommendations you could have.

1,028. Q.—I am working in a small jobbing shop which employs about seven men. Having learned, so to speak, my trade in this shop, would ask you to tell me where and how I could learn the most. We only have a few tools, and by staying in this shop I can only

learn how to use these few. If I could obtain work in a large shop, would I not learn more? I have been working on dies a good part of the time. I find in talking with advanced mechanics that I only know how the work is done by us, and that our way, a good many times, is not always the best.

A.—Many of our best mechanics have learned their trade in small jobbing shops, and we believe that these shops are good places to learn a trade. Mechanics accustomed to work in small jobbing shops can get along better in large shops, should they choose to work in such, than men accustomed to work in large shops can get along in smaller places, should circumstances compel them to do so. In large shops men are liable to become specialists rather than mechanics; neither will they learn to do work in any other way than such as has been established there. Pursue the course you have been pursuing—that is, talk with good mechanics, compare their way of doing work with your way; read good technical papers, and devote your leisure hours to study; be observant; visit larger works whenever you have a chance; do your work faithfully and cheerfully, and we believe you will not regret the time you have spent in the small jobbing shop.

1,029. Q.—How is the gage of saws measured? For instance, gage 22—does it mean 1-22 of an inch, or 22 parts of something else?

A.—Henry Disston & Sons, of Philadelphia, reply that the gage used by them is the same as the Birmingham gage, the sizes of the numbers in which are found in most of the engineering pocket books; 22 is given at .028 inch.

1,030. Q.—Some of our men claim that an ice boat travels faster than the wind; is it true?

A.—It is undoubtedly true that an ice boat may travel faster than the wind, when moving at an angle to the direction in which the wind blows.

1,031. Q.—What is the best article to use for lining an ice chest?

A.—The chest should be lined with zinc leaving a space of about 3 inches, depending upon the size of chest, between the lining and the chest. This space should be filled with very fine charcoal; the cinders from the smoke stacks of wood-burning locomotives are probably the most available, otherwise reduce the charcoal by grinding. Lampblack would be better but is too expensive.

1,032. Q.—What is the precise meaning of the word "oblong"?

A.—The word seems to have no very precise meaning, or at least to be permitted wide departures from precision in practice. Assuming an oblong figure to be a rectangle, one dimension of which is decidedly larger than the other, which is one of the dictionary definitions of it, if we permit the corners of the rectangle to be rounded and still be included in the term "oblong," then, according to the degree of rotundity or curvature of the corners, the figure may be anything from a pure rectangle to an ellipse, and this seems to be the way in which the term is used. In zoölogy and botany the term is permitted a still wider range, as there it is not insisted upon that the two ends of the figure shall be of the same size, as in the case of oblong leaves, etc. The general idea which "oblong" carries is that of length exceeding the breadth, and it is frequently useful, without often conveying wrong impressions. No one may say precisely what the word may be taken to mean, and yet everyone knows very nearly.

1,033. Q.—What is the scale of hardness?

A.—The scale of hardness is an arbitrary, though a generally accepted, one, in which the diamond, being the hardest known substance, is 10; sapphire, 9; topaz, 8; quartz, 7, and talc, 1. Recent investigations at Johns Hopkins University indicate that the difference between 9 and 10 of this scale is fully as great as between 1 and 9, which shows the arbitrary nature of the scale, and also that the expression "between 9 and 10" is not very precise or definite; but it is probably the best that can at present be given.

1,034. Q.—How is carborundum graded?

A.—The numbered grades of carborundum indicate the number of meshes to the linear inch of the screen through which they will pass, No. 8 being the coarsest and No. 220 the finest. The finest powders (not numbered) are obtained by stirring up ungraded powder in water and then allowing it to settle for a definite length of time, after which the upper portion of the liquid is carefully drawn off, and the powder, which then settles from this liquid that is drawn off, is called "6-minute," "10-minute" or "30-minute" powder, according to the time allowed for settling of the coarser particles before the upper portion of

the water is drawn off. The chemical symbol for pure carborundum is SiC. The commercial article contains slight traces of other substances, but they are of no importance.

1,035. Q.—It is claimed that in some parts of the sea the depth, and consequently the pressure, is so great that an iron body, such as an ironclad or a cable, would go down a certain distance and there remain stationary. Is this so?

A.—No. The question of sinking or floating of a body in water is one of the comparative or specific weights of the body and water, and has nothing to do with the pressure. If the body weighs less per cubic foot than water it will float; if more, it will sink, and if it sinks at all it will go to the bottom, no matter how deep the water may be.

1,036. Q.—Of what is the lining of a gas furnace composed? I have some irregular-shaped work to heat with the ordinary glass blow-pipe, and I thought if I could make forms out of composition similar to that used in a gas furnace, I could heat them much quicker.

A.—It seems to us that fire-clay will answer your purpose.

1,037. Q.—I would consider it a great favor if you will describe an incubator to be heated by a lamp.

A.—The incubator consists of a rectangular case usually supported by four legs, giving it the appearance of a table with a very deep top. A lamp is suspended from the bottom of the case, from which the heat ascends through a small flue into a hot-air tank. This tank is placed near the top of the case, is rectangular in form and extends nearly throughout the length and breadth of the case. The tank is very shallow so as to allow sufficient room underneath it for a tray holding pans of water, and for the egg trays which are placed near the bottom of the case. The hot-air tank is connected to an automatic regulator or thermostat. These are the principal features of an incubator. There are different kinds in use, but they are essentially alike in principle, namely, they comprise a case containing one or more drawers or trays for holding eggs, some form of hot-water or hot-air apparatus (usually a lamp for heating), and, in the most practical forms, a thermostat of some kind for regulating the temperature, besides ventilators, appliances for saturating the heated air in the interior with moisture, etc.

Some incubators are also fitted with appliances for turning the eggs without opening the machine.

1,038. Q.—What is the rule for calculating the hight of localities by the boiling point of water?

A.—For this purpose the computations are much simplified by using a thermometer with a Centigrade scale. Under these conditions the following formula may be used:

$$h = 295 \times (100 - t),$$

in which h = meters, and t = degrees Centigrade. For instance, at Madrid the boiling point of water at the mean pressure is 97.8 degrees Centigrade, hence by the above formula we have

$$h = 295 \times (100 - 97.8) = 649 \text{ meters.}$$

The actual hight is 610 meters. This shows that the results by computation of this kind can be taken as an approximation only. To reduce meters to feet, multiply the number of meters by 3.281. According to this, the hight as found above is $649 \times 3.281 = 2{,}129.369$ feet, whereas the actual hight is $610 \times 3.281 = 2{,}001.41$ feet. To reduce Fahrenheit readings to Centigrade, subtract 32 degrees and multiply by 5-9. To reduce Centigrade readings to Fahrenheit, multiply by 9-5 and add 32 degrees.

1,039. Q.—Would it be safe to pass a tube heated to 100 degrees Fahr. through a tank of gasoline, providing it was submerged; would it assist to vaporize the gasoline?

A.—So far as we are aware it would be safe to pass such a tube through a tank of gasoline and then heat it to the temperature named, and it would undoubtedly cause a more rapid vaporization of the oil. All such operations with such a volatile oil must, of course, be conducted carefully and be absolutely controlled.

1,040. Q.—At what temperature does salt water freeze?

A.—Sea water, which contains several different salts dissolved in it, chiefly common salt, freezes at 27.4 degrees Fahr., the salt separating, and the pure water floating in the form of ice; and water which is saturated with sea salt sinks as low as —4 degrees Fahr. before freezing. Pure water freezes at 32 degrees Fahr., or we may say that the freezing point of pure water is stationary at 32 degrees.

1,041. Q.—Which is the best way to pipe a room for direct-expansion

refrigeration? A holds that a continuous pipe line is the right thing. B says he finds it more efficient to divide the piping into sections, feeding from manifolds.

A.—You ask how to pipe a room, and we haven't got the room, so that we do not know whether it would be best to arrange the piping all in one continuous coil or feed from manifolds. We may say, however, that the length of pipe in one coil for direct expansion of ammonia depends on the size of the pipe; 2-inch pipe can be anywhere from 1,000 to 2,000 feet in length. If the coils are subdivided and made too short, there is difficulty in regulating exactly the supply of liquid to each coil. In many cases where the amount of space to be cooled calls for very short coils to secure the necessary temperatures, it is customary to connect to the coils of the next room until the desired length is secured, where this is possible. Otherwise, where the room is small, pipe of a smaller diameter may be used. Where very small indeed, as in cooling a large number of refrigerator boxes of small cubic contents, the direct expansion is abandoned altogether and brine is used.

1,042. Q.—In firing a rifle or cannon, why does not the breech receive the same impulse or blow as the ball?

A.—It does.

1,043. Q.—I discovered a few weeks ago a very useful machine. How can I bring this machine before the public? There is nothing of the kind in the market.

A.—If you have not the means to build the machines and place them on the market, we should advise you to give it into the hands of a first-class business man. If you have means, build them yourself and advertise judiciously. If the machine is good for anything, you will not have much trouble in making it known to the public.

1,044. Q.—Is the glass tube in a spirit level straight or not? If it is, what draws the air bubble to the center of the glass?

A.—In an ordinary spirit level, the glass tube is slightly bent so as to form an arc, the highest part being placed upward. In some very fine spirit levels the inside of the tube is ground to a larger diameter in the center than at the ends. The air bubble always seeks the highest point, hence when the tubes are in a level position the air bubble will be in the center.

1,045. Q.—For painting a stand-pipe 12 feet diameter and 110 feet high, what will be the best method of reaching the top?

A.—Probably the best way will be to make a hook out of ¾-inch round iron about 3 or 4 feet long before it is bent, with an eye having a 1½-inch hole forged to one end; the branch of the hook having the eye should be about one foot long. To this eye lash a two-sheave block and then take a one-sheave block with sufficient fall for the hight. Any "tar" will be able to hoist this by means of a pole and ladders and hook it over the top of the stand-pipe. After this has been placed in position the mode of procedure will suggest itself.

1,046. Q.—A man lifted 300 pounds, and in doing so injured his back. What caused the injury, an improper *stress* or an improper *strain?*

A.—From a mechanical standpoint, stress is distributed force, and tends to change the shape of a body; strain is the amount of change of the shape of the body caused by the applied stress. We should therefore say that the man injured or strained his back by an excessive stress.

1,047. Q.—Can one side of an article of rubber be soft and pliable and another of a stiff and harder nature in the same mold?

A.—An article of rubber, one or more parts of which shall be soft and pliable and the remainder hard, can be made by placing packing in the mold containing a small percentage of the vulcanizing agent, which will vulcanize soft, in those parts of the mold where it is desired to have the parts flexible. The remainder of the mold should be packed with rubber containing a large percentage of the vulcanizing agent employed, which will vulcanize hard. The line of demarkation between the hard and soft rubber will depend entirely on the care with which the mold has been packed, and the amount of flexibility of the soft parts will depend on the degree of hardness to which the soft rubber vulcanizes, and the thickness and the density of it.

1,048. Q.—What ingredients are used in the manufacture of india rubber?

A.—The composition of india rubber usually consists, first, of a mechanical mixture and afterwards of a chemical combination of caoutchouc with other ingredients, such as lampblack, red oxide of mercury, silica, pulverized pumice, etc. The latter are used as coloring matter and as adulterants. To these in-

gredients is also added—and thoroughly mixed with them—a percentage of some vulcanizing agent, usually sulphur, varying from 4 per cent. upwards, according to the degree of hardness desired and the temperature at, and the time in which, it is desired to vulcanize it.

1,049. Q.—I intend, some time in the future, to take a full course at some technical school. I made inquiries in regard to what books besides geometry and algebra I should get in order to post myself a little before going. I was told that they would sooner not have me read any books at all, as I would be getting false views in my mind, which would be harder to get out than to get truth in. What is your opinion of this?

A.—The advice given you is not good. Our advice is, if you cannot enter a technical school at present, do not lose any time, but provide yourself with good books, and study all you can. There are many technical institutions to which you will not be admitted unless you can pass an examination in various branches of technical knowledge.

1,050. Q.—A certain manufacturing concern ordered of a zinc manufacturer two or three hundred pieces of No. 26 zinc cut to size. The concern wanting the zinc supposed the zinc, sheet iron and other similar metals were all measured under the same gage. On the arrival of the zinc ordered, they found that, instead of No. 26 wire gage, it was 3/8 inch thick. The zinc company was notified of the error and claimed that a special gage was used for zinc, and that No. 9 zinc gage was the same as No. 26 wire gage. Is there a recognized standard zinc gage?

A.—There are gages for nearly all purposes, and no gage in particular can be called a standard. It is generally stated that the Birmingham wire gage is for iron and steel only, but we believe it is used by some for zinc, copper, brass and lead. There is another Birmingham gage for sheet brass, gold, silver, and other metals, but what these metals are cannot be determined. There are also special gages for zinc, but they do not agree. There is an American gage, there are wire gages all differing from each other, and various firms have gages of their own. The whole system is an extremely senseless one and serves only to create confusion. The system should be ignored, and in giving an order the thickness should be stated in fractions

of the inch, or, if preferred, the weight per square foot, when plates are ordered, or the weight per hundred feet of wire when the latter is ordered.

1,051. Q.—What is the best angle of spiral for milling cutters and twist drills?

A.—We do not know. The usual angle for milling cutters is about 12 degrees, but a much greater angle has been used by the Pratt & Whitney Company (and perhaps others) for some work with good results. Twist drills vary somewhat, but are usually about 20 degrees.

1,052. Q.—Of what minerals are the Arkansas and Washita oilstones composed?

A.—These stones are of the mineral called "Novaculite." The rock consists of extremely minute grains of quartz, among which are small cavities left by the dissolving out of calacspar crystals that were originally in the rock. Volume III of the Arkansas Geological Survey Reports for 1890 treats of the novaculites and all other whetstones. The volume can be obtained of the Secretary of the State of Arkansas at Little Rock.

1,053. Q.—What material is used for deadening the sound through floors?

A.—Lay two floors about one inch apart, and fill the space between them with Portland cement.

1,054. Q.—Which is the proper way to order iron, studs, set-screws, etc., ⅞x2 inches, or 2x⅞ inch, ⅞ being the diameter, and 2 inches the length, and in flat iron should we say ½x1½ inches or 1½x½ inch?

A.—In ordering studs and screws, we would always give the diameter first, and with flat iron we would give the larger dimension first. It is probable that this represents the most general, but not the universal practice.

1,055. Q.—What is a suitable paint for a blackboard?

A.—Give the board a coat of ordinary black paint that will dry with a gloss; then apply a coat of black paint mixed with turpentine instead of oil, which will dry a dead black. These you can get mixed ready for use in any ordinary paint store. Another way is to use pulverized slate or quartz rock moistened to the consistency of a thick fluid with silicate of soda, and applied to the board with a brush; this will give a good imitation of slate, and is said to last a long while.

1,056. Q.—What is the usual stress allowed per square inch for rawhide, and what is the limit of elasticity of same?

A.—We have found it extremely difficult to get any reliable data. Some crude experiments seem to indicate that its tensile strength will reach 12,000 pounds per square inch, while leather, such as belting, only reaches about 5,000 pounds. The common load for leather belting in running is only about one-twentieth of this.

1,057. Q.—Can you tell me anything about the use of a steel triangle in place of a gong for signaling or calling? How is it made, how is it used, and how good is it?

A.—There is, of course, no novelty about the triangle. As a developer of clear and penetrating sound, it is not to be despised. The fact that it must be suspended freely and cannot be held in a fixed position, so that a mechanically operated striker can be used, has prevented its more general adoption. The Arthur Company, Front street, New York, have a triangle in their shops, located near the office door and used for calling some of the floormen, wherever they may happen to be. The sound of the triangle is there considered much preferable to that of a gong, being easily heard in every portion of the four-story building. The triangle spoken of is not large. It is made of ⅞-inch steel, the sides of the triangle being each about 21 inches. It is suspended by a ¼-inch round leather strip, probably a piece of round leather belting, and it is struck near the middle of the side opposite the opening by a small hammer that is kept near it on the bench. The angles of the triangle are not sharp; the ends of the steel at the opening curl outward a little, and in the curve taper to a sharp edge crosswise of the steel. The steel is not tempered. Triangles have proved very effective in some cases for fire alarms and for signals. Aluminum seems to have peculiar sonorous properties, and probably triangles made of this material, with a little alloy for hardening, would be much superior to those of steel.

1,058. Q.—What metal in the shape of, say, ⅜-inch round rod, would show the most expansion lengthwise?

A.—Zinc.

1,059. Q.—At what temperature would it begin its expansion, and how high degree of heat could it attain before melting?

A.—Zinc, or other metals, expands as soon as heat is applied. The melting point of zinc is 780 degrees Fahr.

1,060. Q.—In what ratio would it expand as to its temperature—that is, if at 200 degrees it expands ⅛ inch, would it expand ¼ inch at 400 degrees?

A.—The expansion is not quite regular for equal intervals—as degrees—of heat. The variation in this respect is not, however, sufficient in extent to be of great importance to the man who wants to know something about the matter for practical purposes. Zinc will expand .00017 of its length for every 10 degrees of increase of temperature, very nearly.

1,061. Q.—How can I determine how much weight a cask will support in fresh water?

A.—By finding the difference between the weight of the cask and the weight of a quantity of water equal in bulk to the cask.

1,062. Q.—What does a cubic inch of fresh water weigh?

A.—.0361253 pound.

1,063. Q.—Does heating air take all the moisture from it?

A.—Heating air takes no moisture out of it. The effect is only to increase its capacity to absorb moisture.

1,064. Q.—Suppose a man to stand on a pair of scales in an elevator at the top of a high building, and the elevator begins to descend at a uniform rate of 20 feet per second. When the falling man catches up to the descending elevator, will the scales immediately register his full weight, or more or less, or when would he regain his original weight?

A.—If the elevator were really to begin to descend at 20 feet velocity (a thing which, in point of fact, it could not do), it would leave the man behind it in the air, as gravity acting on his body could only impart this velocity after a lapse of time. At the end of this lapse, the man and the elevator would be traveling downward at the same speed, but the man still in the air falling freely. His velocity would continue to increase, and he would finally overtake the elevator. At the moment of impact he would be traveling faster than the elevator, and the scales would register more than his true weight. Under actual conditions, the elevator and the man gain their velocity together, and the true weight would be shown as soon as both reached a uniform speed, whatever that might be.

1,065. Q.—What metal will give the greatest quotient when its elastic limit is divided by the specific gravity?

A.—In regard to the elastic limit, authorities differ considerably in their data on this subject, and all that can be done is to adopt a tolerable approximation. The following table gives elastic limit of the principal metals used in structural work, the specific gravity of each, and the quotient obtained by dividing the former by the latter:

Metals.	Approximate Limit of Elasticity.	Average Specific Gravity.	Quotient.
Copper, cast	6,300	8.7	724
Cast-iron	4,500	7.15	629
Wrought-iron in either bars, sheets or plates. .	20,000 to 40,000	7.77	2,574 to 5,148
Steel, bars	34,000	7.85	4,331
Lead, sheet	1,100	11.38	96
Tin, cast	1,500	7.35	204

1,066. Q.—In an account of an air ship, with which Mr. Maxim is said to have had something to do, there is a statement to the effect that the section of the ship is double, and is filled with hydrogen gas confined in separate compartments. What is the object of this, is it to increase the buoyancy of the air ship?

A.—There is really in mechanics no such thing as buoyancy. When we speak of a thing as being buoyant we mean simply that it is lighter than the element in which it is immersed or on which it floats; such, for instance, as water or air. Hydrogen gas is lighter than air, and therefore if the air is excluded from the chambers formed in the double section of this ship and hydrogen gas takes its place the specific gravity of the ship as a whole is thereby lessened. It would be still further reduced, however, if the air were to be pumped out from these spaces and nothing put into its place; that is to say, if a vacuum could be produced in these spaces and maintained. This, however, would subject the walls of these spaces to unbalanced atmospheric pressure which they are probably not able to withstand, but which they can stand when the internal pressure of hydrogen gas is made nearly, or perhaps quite, equal to atmospheric pressure.

Gas is not put into an ordinary balloon to "make it lighter," but to distend it, and thereby make it displace a volume of air which would weigh more than the combined weight of balloon and contained gas. If the gas could then be taken out, leaving a vacuum without collapsing the balloon, it would be more "buoyant" still.

1,067. Q.—Does the rim or the hub brake as applied to a bicycle produce the greater strain on the spokes?

A.—We do not think an exact analysis of the strain per spoke can be made, though it is easy to see that the total load is greater with the hub brake, as in this case the effect is a turning effort on the wheel, the same as that due to driving the machine, though in the opposite direction; the inertia effect of the machine and rider being, however, multiplied at the hub by the ratio between the diameters of the wheel and the brake surface. With tangent spokes the strain is of course borne equally by all the spokes leading in one direction; that is, by one-half the total number of spokes. With the rim brake, as ordinarily placed, the effect of applying the brake is to put a bending strain on the wheel as a whole, the wheel being in the condition of a beam supported at both ends and loaded in the middle, the load being equal to the inertia effect without multiplication. The strain on the spokes is essentially the same as that due to the load on the machine when being ridden . Such a load on a wheel with tension spokes is well known to be divided among all the spokes of both systems, except a few near the point where the load is applied. Nearly twice as many spokes will thus be seen to carry the load in the case of a rim brake as in the case of a hub brake, but the total strain is more than doubled with the hub brake. The strain per stroke is thus greater with the hub brake, but how much greater it is impossible to say, as the number of spokes which do not assist in carrying the load on a tension spoke wheel is uncertain.

1,068. Q.—Is it true that a cyclometer will register a greater distance traversed by a pneumatic-tired bicycle ridden by a heavy man than when ridden by one of light weight, the actual distance, the condition of the tires and other particulars being the same in each case?

A.—It is true, although the difference will be small. The

compression of the tire under the weight of the rider reduces the working radius of the wheel, and for a heavy rider of course more so than for a light one; so that for a long distance the wheel ridden by the heavy man would make more revolutions than for the other. A simple experiment will demonstrate the principle. Take an unloaded bicycle on a smooth floor, and back it against a wall for a start. Mark the tire, with a pencil or otherwise, so that a complete revolution of the wheel can be noted. Move the bicycle in a straight line until a complete revolution of the wheel is made and place a box or other suitable stop befo.e the wheel at that precise point. Now let a man get on the wheel and start in a straight line as befor , and it will be found that when the revolution of the wheel is completed, the wheel will not reach the box where the wheel stopped before by perhaps a couple of inches. The difference in travel for men of different weights may be only ¼ inch, or more or less, according to the difference of weights. In a case we actually tried, with a rider of average weight on the wheel, the length of tire bearing was about 6 inches on the floor, and the travel for the revolution was about 2 inches less than for the wheel without load.

1,069. Q.—Suppose we have a bicycle with large sprocket wheel 5 inches in diameter, and that the length of the crank is 6½ inches, what pressure would be required on the pedal to bring a stress of 1,200 pounds upon the chain?

A.—The weight required would be inversely proportional to the radius of the sprocket wheel, and the expression in the form of a proportion would be 6.5 : 2.5 :: 1,200 pounds is to the required weight, and this reduced gives a weight of 461 pounds.

1,070. Q.—What are advantages of the metric system of measurement over the English system, and would not its adoption be an inconvenience to thousands of workmen who have always used English measurement?

A.—The chief advantage claimed by the advocates of the metric system are that calculations are more easily made than in the English. Its adoption would undoubtedly inconvenience both workmen and manufacturers.

1,071. Q.—If a force of 10 tons is traveling at a rate of 100 feet per minute, will it continue to move at the same rate of speed when

it is made to lift a load of 5 tons at the rate of 200 feet per minute? Or will it come to rest on account of the force and resistance being equal? I cannot understand how two equal and opposing forces can keep in motion, and if I mistake not, this is the very thing all engines are doing which are fully loaded. Take, for instance, a lever with a fulcrum at its center, and with a load of 100 pounds at each end; this lever will never move unless some outside force acts on it.

A.—When a force acts upon a body, a secondary force, or a force of reaction, is at once set up, equal and opposite in direction to the primary force. These forces are said to be in equilibrium, and they neutralize each other's effects. Consequently such a set of forces cannot change the state of a body with respect to rest or motion. If the body is at rest it will remain so, or if in motion its motion will remain unchanged, so far as these forces are concerned. This agrees with Newton's first law of motion, namely: Every body continues in a state of rest or of uniform motion in a straight line until compelled by impressed forces to change that state. In a steam engine the pressure of the steam has to overcome certain resistances, and when the engine is running at a uniform rate of speed, the force exerted by the steam is equal to the force of the resistances, and since the engine cannot of itself change its motion, it must continue to move at a uniform rate of speed. The same holds true for the problem of the lever cited by you. Here we have three forces acting on the lever, namely, the loads at the ends and the reaction of the fulcrum, and these three forces are in equilibrium, and if the lever is at rest it will remain so, until some other force acts upon it to change this state of rest. In your first problem the work performed by the force of 10 tons in lifting the weight of 5 tons is equal to the resistance of this weight into the distance through which this resistance is overcome, consequently the system is in equilibrium, and when the force has attained a velocity of 100 feet per minute in lifting the weight and then moves at a uniform rate, it will continue to do so unless some other force comes into play to change this state.

1,072. Q.—Can I receive copies of any patent by forwarding to the Commissioner 25 cents in stamps?

A.—Stamps are not accepted by the Commissioner. The price of uncertified printed copies of patents is now fixed at the uniform price of 5 cents each for single copies. In ordering a copy of any patent, give name of patentee, invention, number and date of patent.

1,073. Q.—What is the best way to apply for a patent? Is it best to employ a lawyer or agent, or to apply to the office direct?

A.—Unless you are skilled in matters of patent law, and in drawing up specifications and claims for a patent, it is decidedly preferable that you employ a person who is skilled in such matters, because, unless skill is used, a patent, even if secured at all, is likely to be valueless.

1,074. Q.—I have an invention which I am thinking of patenting. Will it be safe to show it to some manufacturer, with a view of interesting him in the matter of furnishing the means of a patent?

A.—We should have no hesitancy in showing it. Everyone who sees it will be a witness of your invention. If you have any doubts, show it to one or two friends and get them to make a memorandum with reference to it.

1,075. Q.—Would it be infringing on anyone's patent to make a shaking grate if it were made substantially unlike any in use?

A.—No; there is no patent on shaking a grate bar, although there are several on a shaking grate bar.

1,076. Q.—Suppose I obtain a patent embracing several improvements on a mowing machine, one of the parts improved being the pole; would my patent give me control of the use of the improved pole on other machines, such as harrows, etc., or would it be necessary to obtain a separate patent for the pole?

A.—You should obtain a separate patent on the pole.

1,077. Q.—Can a person who claims a patent for an invention for parting hair by air-blast with a common bellows, prevent me from using or patenting my invention, in which I employ compressed air with another kind of bellows or apparatus for making the air-blast?

A.—The party who first invented and made an apparatus to part hair with an air-blast from compressed air of a bellows, especially arranged and adapted for that purpose, could take out a patent with claims broad enough to cover that new application of mechanism for that purpose, so as to make any modi-

fied form of the air-blower subordinate to his claim. But you can claim and patent, and he cannot use without infringing on you, any new kind of air-blower, of different mechanical combination for the same purpose as his, if it be of your invention. But you could not use it without infringing on his invention; provided, as we said, he was the first to invent and use a machine of that kind for that purpose, and that he has a patent covering it that has not expired.

1,078. Q.—If A, as my draftsman, under my pay, designs certain mechanical apparatus, which I patent in his name and manufacture as a staple article, can he claim royalty of me or prohibit me from manufacturing the goods after he leaves my employ? Again, if, under a misapprehension, I should agree to pay him a royalty, would I be bound by such an agreement, if I found I was mistaken in the premises, and that a royalty would have been unnecessary?

A.—If the patent is in the name of your draftsman, without assignment to you, either in the patent or afterwards, he can hold everything that the patent entitles anybody it. Because a man sells his services as a draftsman to you, it does not follow that he sells all his future prospects. When a man secures a patent in his own name, without assignment, nothing but some future action on his part can deprive him of the advantages of it. This answers both questions.

1,079. Q.—A is running a machine shop, building special machines. B is foreman for A at $3.00 per day for 10 hours' work. When 6 o'clock comes, is not B free from A till 7 o'clock next morning? On Saturday night or Sunday B reads his mechanical papers. In one of the papers B sees a cut of a machine entirely different from A's machines, from which he gets the idea to build a machine to do the same work as A's machines, but different in construction. B designs and makes drawings for the machine in his own time, and takes same to A to have model made. A sees them, and claims the drawings and design of the new machine belong to him, and that B has done A an injustice. Whom does the machine belong to, A or B?

A.—In the absence of any special agreement, the design belongs to the man who made it, and the courts have repeatedly so decided.

1,080. Q.—Has an inventor a right to manufacture and sell an article for which he has applied for a patent in the United States?

A.—Yes; but the articles should be marked "Patent applied for."

1,081. Q.—Has an inventor a right to use the word "Patented" before the patent is granted?

A.—No; we cannot see how any person can expect to have a right to claim to have that which he has not.

1,082. Q.—Would I be liable to prosecution by making a model of a patented machine?

A.—If you make a patented device to use or to sell you are liable to prosecution for infringement. You have a right to experiment with a patented device with a view to determine whether or not it will work according to specifications. If you want to build a model machine involving somebody's patent, it would be no more than courteous to write him asking permission, which would undoubtedly be granted.

1,083. Q.—When there is a chance of improving a patented article, can this improvement be patented without getting into trouble?

A.—The improvement can be patented, provided you do not infringe on the original patent. In questions of infringement, points may arise which require experts to decide upon. A good patent solicitor should be capable of giving you good advice in the matter.

1,084. Q.—A invents a machine, and as there must be considerable experimenting on it, he assigns three-quarters of the interest in the invention to B, C and D (one quarter to each), he receiving a regular salary from them and retaining one-quarter interest in the patent. The machine proves to be a success; two of them are built and the patents are granted. A, the inventor, and D, the managing partner, have a falling out, and D refuses to have anything more to do with A or with the patent. D has a business "pull" with B and C, which prevents them from doing anything contrary to his wishes, and he has both the machines stored away on his premises, refusing to give them up or exhibit them. Can A manufacture and sell these machines without the consent of the others?

A.—If the assignment contains no special clause which prevents, he can. That is to say, if the assignment is simply one-

quarter undivided interest in the patent without special limitations, either one of the owners can manufacture and sell the machines without accounting to the others, all being on an equal footing in this respect, so far as the rights granted under the patents are concerned.

1,085. Q.—Will he have to pay them a royalty?

A.—Not unless the terms of the assignment or some special arrangement requires him to do so.

1,086. Q.—Can he compel D to give up the whole or part of the property in his possession?

A.—If the terms or agreement under which they were built are such that A actually owns one-quarter interest in them, he can compel D to give up the property or pay the value of his interest. This would be a question for lawyers or a court to decide, and would be independent of the patent. It is simply a question of property rights, regardless of the patent.

1,087. Q.—If A can buy B's or C's interest, thus giving him one-half interest, will he be any better off?

A.—He will have no greater or better right to manufacture and sell. He will simply have acquired one other man's equal right to manufacture and sell under the patent, which may be worth much or nothing, depending upon circumstances.

1,088. Q.—Has the inventor, owning a part interest, any rights which an assignee, owning an equal interest, does not have?

A.—No.

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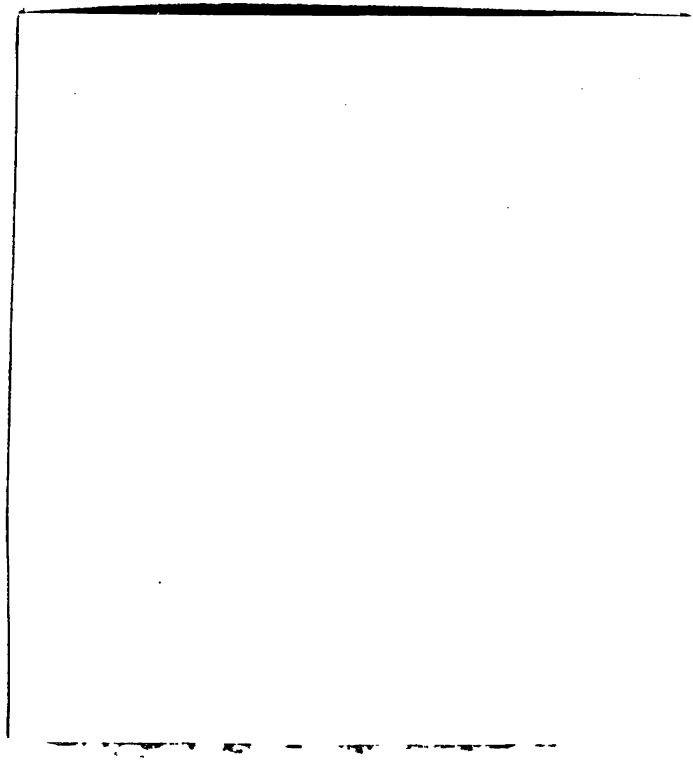

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